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REPORT

TO THE

BOARD OF TRUSTEES

"COMMISSIONERS OF WATERWORKS"

COMPLIMENTS
OF THE
BOARD OF TRUSTEES
"COMMISSIONERS OF WATERWORKS"
CINCINNATI, OHIO

I, OHIO

GEO. H. BENZENBERG, CHIEF ENGINEER

A BRIEF HISTORY OF THE OLD WATERWORKS, LEADING UP TO AND INCLUDING THE CONSTRUCTION OF THE NEW WATER-WORKS BY AND UNDER THE "COMMISSIONERS OF WATERWORKS."

1909

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CINCINNATI, OHIO

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Died November 6, 1904.

G. H. BENZENBERG.

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G. H. BENZENBERG.

CHAS. HERMANY,
Died January 18, 1908.

Chief Clerk.

D. J. BLACKMORE,
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J. F. WILSON,
Died April 18, 1904.

ELMER E. HUMPHRIES.

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Assistant Chemist.

Assistant Engineers.

C. N. MILLER,
In charge of Office.

WM. C. JEWETT,
In Charge of Settling Reservoirs.

ALFRED PETRY,
Died May 14, 1901.

JOHN A. HILLER.

In charge of Pump Pit, Tunnels, Main Station, Western Hills Station, and of Reinforcing the Distribution System.

E. G. MANAHAN,
In Charge of Filtration Plant:

Mechanical Engineer.

E. CEDARSTROM,
Resigned January 30, 1900.

H. AXFORD,
Resigned March 31, 1903.

S. VIVIAN,
Died July 12, 1906.

S. G. POLLARD.

Chemist in Charge of Laboratory.

JOSEPH W. ELLMS.

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Draughtsmen.

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Mary Callahan. Nicholas J. Gough. Frank C. Maphet.

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A. F. Nagle. James Bailey.

Inspectors on Valves.

C. L. Howes. S. Howarth.

Inspectors on Cast-Iron Pipe.

Wm. N. Stites. Isaac Albertson. Fred Brachmann.

IN THE FIELD.

Assistant Engineers.

Jas. A. Stewart.	H. L. Conway.	A. P. Birnbaum.
Robt. J. Devenish.	G. E. Jones.	C. A. Knowlton.
A. S. Hobby.	R. L. Engle.	G. T. Smith.
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Robt. Legner.	Fred C. Deerr.	Samuel Hirst.
T. G. Trainor.	H. A. Parker.	

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REPORT

OF THE

CHIEF ENGINEER

CINCINNATI, OHIO, February, 1909.

TO THE BOARD OF TRUSTEES,

"COMMISSIONERS OF WATER WORKS," CINCINNATI, OHIO.

Gentlemen — Having been requested by your Board to prepare a historical and descriptive review of the work performed under the direction of your Board in improving and extending the Water Works of the City of Cincinnati and in the betterment of the character of the water supply, I herewith transmit such review together with such photogravures of the work during and after construction as will aid in a full comprehension of the same.

The Annual Reports of your Board and of the Engineering Department having consisted of only a concise statement of the legislative, legal, and financial features of the work, together with a brief report of the various contracts which were awarded and of the progress made under them, these reports contained very little which would give any very adequate idea of the character and extent of the betterments undertaken by you. This review, therefore, at this time, will supply the information not contained in these reports, and does so, perhaps, in a more acceptable form than if the same had been scattered upon the pages of the Annual Reports.

It may not be inappropriate to add a brief chapter of the earlier history of the Cincinnati Water Works and the conditions which led up to the legislative act which authorized the appointment of your Board and vested it with power to carry out the purposes of the act. In preparing this I have made use of the historical account of the Cincinnati Water Works, written by Thos. J. Bell in 1880 while he was Assistant Superintendent of the department.

According to this account, the lower site of the present city was plentifully supplied with flowing springs, which served the early settlers for all purposes for many years; then, as these became insufficient, some enterprising citizens began to sink wells and equip them with hand pumps, and, as early as 1799, to exact a payment of twenty-five cents a week from any family using water from such well. This was followed by carting water from the river in casks mounted on wheels, and in 1805 seventeen hundred inhabitants were thus supplied by one party alone. Public wells were from time to time constructed in different localities and other means adopted to meet the wants.

The necessity of a more satisfactory method of supplying water to the inhabitants and of furnishing fire protection became constantly more evident, so that on March 31, 1817, the Town Council adopted an ordinance which should be the means of providing a suitable Water Works for the growing town. This ordinance, among other things, stipulated "that the Cincinnati Manufacturing Company, their heirs, successors, and assigns shall be, and they are, hereby vested with the exclusive privilege of conveying water, by tubes or otherwise, from the Ohio River, through the streets, lanes and alleys and commons of the town of Cincinnati, for the purpose of supplying the inhabitants of said town therewith; which privilege may and shall be enjoyed by the said Company, their heirs, successors, and assigns, exclusively, as aforesaid, for the term of ninety-nine years from and after the passing of this ordinance, on the following terms:

"1st — The said Company shall complete the work so far as to convey the water into that part of the town lying south of Third Street, commonly called the bottoms, within two years from and after the first day of July next; and they shall convey the water into that part of the town lying north of Third Street, commonly called the hill, so that the same may be delivered three feet above the first floor of James Ferguson's kitchen, in the Second Ward of said town, within the term of three years from and after the said first day of July." It further stipulated, in addition to other usual provisions, that the Company should furnish water for fire protection free of charge, and that "their heirs, successors, and assigns shall pay to the Town Council, yearly, and every year during the continuance of the privileges herein granted, the sum of one hundred dollars, which payment shall commence one year after the works are completed." Also that "during the term of ninety-nine years — no other person or company shall be permitted to convey water through the streets, lanes, alleys, or commons of the town by tubes or other conductors for the purpose of supplying the citizens of the town with water," and, further, that if "the said Company be dissolved before the expiration of the aforesaid term of ninety-nine years, this ordinance and the privileges herein granted shall not hereby cease, but shall continue in full force and effect, and at the dissolution of the said Company all the privileges herein granted shall vest in the persons composing said Company, at the time of such dissolution, their heirs and assigns."

Notwithstanding the remarkably exclusive privileges granted by this ordinance, the Company seems to have lacked either ability or the funds necessary to construct such extensive works, and the time for supplying water to the "bottoms" was extended to July 1, 1820. Early in that year the Company transferred all its interests and rights to Sam W. Davies, who completed Cincinnati's first Water Works, the first water being drawn from a wooden penstock on July 3, 1821.

These Works consisted of one set of pumps located on the present site of the Front Street Pumping Station, which delivered the water from the river to a tank on the north side of Front Street, where similar pumps, taking the water from this tank, delivered the same into a reservoir on the hillside, a short distance south of the present Third Street reservoir. The pumps were operated by horses or oxen working a circular treadmill. The machinery, buildings, pipes, and reservoirs were all constructed of wood. The reservoir was 30 x 40 feet in size and six feet deep, with sides and bottom lined with oak timber. The pipes consisted of logs ten inches in diameter and twelve feet in length, with a two-and-a-half-inch hole bored through them and banded with iron hoops.

The Water Works did not prove to be a profitable enterprise for its owner, and trouble soon arose because of failure to pay the annual fee, to extend the pipe lines and penstocks for fire protection as required, or to furnish sufficient quantity of water, the latter largely due to a great wastage of water on the part of the consumers. A committee was appointed by the Council to investigate the Works, and it reported "the Reservoir to be in excellent order, the water clear and pure, and in a Holesome state."

To prevent wastage, the owner shut off the supply during the night, and this brought about another investigation by a committee appointed by the Council on October 15, 1823. This committee reported that the payment of money was in arrearage, that the proper number of penstocks had not been erected, and that the water was kept off during the night, and recommended that in case the owner of the Water Works failed to comply with the terms of the contract that the charter be declared forfeited. In order to prevent wastage, the Council passed an ordinance fixing a fine of ten dollars against any person convicted of wasting water unnecessarily.

On account of increase in consumption and waste, the owner was compelled early in 1824 to put in new pumps, operated by a single steam cylinder engine taken from the steamboat "Vesta." The beam and flywheel were of wood, as were the two lifting pumps, while the two force pumps were made of iron. These pumps had a capacity of 1,200,000 gallons per twenty-four hours. The old pumps were abandoned. To meet this expense and that for pipe extension, the owner became financially embarrassed, and he offered to sell the Works to the city for $30,000.00.

A committee appointed by the Council thoroughly investigated the subject, and presented a long report, stating the Works were in very good condition, and submitting the cost of operation, the gross revenue, the character of the indebtedness, and recommended that the city purchase the Works at the price offered. The proposition was sub-

mitted to a vote by the freeholders, who, on March 3, 1824, rejected the same by a vote of 294 to 25.

Hereupon the owner interested a number of prominent citizens in the formation of a corporation which should acquire and operate the Water Works. After a very careful examination of the entire property, its income and expenses, the Cincinnati Water Company was incorporated under special act of the Legislature, passed January 7, 1826, limiting its capital stock to $75,000.00.

During the following years the Company constructed three new reservoirs of stone and earth embankment on the site of the present Third Street reservoir, in 1828 laid an eight-inch iron pipe, which until 1845 constituted the only supply pipe to the city, and in 1832 erected an additional steam pump of three million gallons daily capacity.

In December, 1831, a fire destroyed the pumps and part of the building, which left the city out of water for over three weeks.

Early in 1832 the Council appointed a committee with the view of the city purchasing the Works. This Committee submitted an elaborate report, stating that if, by act of the Legislature, a principal superintendent of the Water Works could be appointed for a period of years, that the revenue of the Works would not only defray the yearly expenses and make the necessary repairs, but after reducing the rates twenty per cent in 1838, the same amount in 1840, and ten per cent in 1850, would still leave a surplus fund in 1870 more than sufficient to pay off the loan required to purchase the Works and to make needed improvements and extensions, and concluded with the recommendation that the city purchase the Works for $150,000.00 This proposition was submitted to a ballot, and on March 10, 1832, was defeated by a vote of 617 to 303.

The city declining to purchase the Works, the Water Company decided to increase the capacity of the Works, and applied to the Legislature for authority to increase its capital stock, which, at the instance of the Council, was then refused, but four years later was granted after the Council had withdrawn its objections. Meanwhile the agitation in favor of municipal ownership was being kept up until the Council, on December 2, 1835, appointed a committee to confer with the representatives of the Water Company as to the terms on which the Company would sell. One week later this committee reported that the Company would sell for a sum equal to the net revenue of that year capitalized at six per cent. Thereupon the Legislature, on March 11, 1836, at the request of the Council, passed an act authorizing the city, after submitting the matter to a vote of the citizens, to purchase the Works, and for that purpose to borrow money at a rate of interest not exceeding five per cent, stipulating that the Water

Works be managed by four judicious and competent freeholders. Ten days later the Council Committee presented a complete and carefully prepared report, recommending the purchase of the Works for the sum of $273,637.00, and setting forth their reasons together with an estimate of the annual revenues and expenses for the succeeding ten years, showing a net profit each year which would be sufficient in time to pay off the loan of $320,000.00. This proposition was, on April 1, 1836, submitted to a vote of the citizens, and also defeated by 1,274 votes being cast in opposition to the purchase and 956 in favor thereof.

In 1838 the Company raised the water rates fully twenty per cent, which created such general indignation that the Council in June of that year appointed a committee to examine the books of the Company, and again confer with it relative to the purchase of the Works. This Committee, on August 29, 1838, submitted a very brief report, showing that the expenses of operation had been largely increased, while the revenue had slightly decreased, and that there was no certainty of the surplus becoming in time sufficient to wipe out the debt, but the report concluded with the recommendation that the question of purchase be under the act of March 11, 1836, again submitted to a vote of the people, giving as a reason the dangerous and exclusive powers which the Company possessed under its charter. The recommendation was accepted, and a vote by the people had on the subject on the fourth Tuesday in October, 1838, which this time resulted in a large majority being in favor of the purchase, the vote being 1,573 in favor and 521 against purchase. A question having arisen as to whether the Act of 1836 was any longer applicable, the Legislature, on March 16, 1839, passed a new act, authorizing the city to borrow $300,000.00 at a rate of interest not exceeding six per cent, and to apply the same to the purchase of the Water Works. On May 3, 1839, a vote was had under this act on the question of purchase with the following result, there being 728 votes in favor and 553 against purchase, showing a remarkable decrease in the vote in favor of acquiring the Works.

The articles of agreement for the transfer of the property were immediately prepared, and on June 17, 1839, were ratified by the Council, and eight days later the city took possession of the Water Works, paying $300,000.00 in city bonds, bearing six per cent interest and redeemable in 1865. The officers of the Company were retained until September 15, when the City Board of Directors took charge of the Works, after having duly organized and appointing Sam. H. Davies as Engineer. The Works then consisted, aside from the real estate, of the reservoirs on High Street, the two pumping engines and appurtenances, and of three and a half miles of iron pipe and nineteen miles of wooden pipe of 1½ to 2½ inches interior diameter. In March, 1840, the Legislature

passed a law making, among others, the office of Engineer of the Water Works elective, and providing for a Superintendent of the Works, which office was to be filled by appointment by Council. This law the Council deemed an interference and made it the subject of some amusing ordinances.

In his first Annual Report the Superintendent calls attention to the very high rate of average daily consumption and the heavy loss of pressure, and makes comparison with that of Philadelphia. He attributes the principal reason to the great leakage from the wooden pipes and the small diameters of these pipes, and deprecates the laying of any more of that kind of pipe, and recommends the replacing of the same with iron pipe instead of spending money in constantly repairing wooden pipe. This had the effect that it ended the further laying of any such pipe, and the complaints of damages to property due to leakage hastened the substitution of iron pipes during the following years.

It becoming very evident that additional pumps must be provided, the Directors adopted the design of Mr. Geo. Shield for a new pumping engine of five million gallons daily capacity, and awarded the contract for its construction to Messrs. Yeatman and Shield on the price per pound basis for the different kinds of metal employed. This gave rise to considerable controversy when the contractors included the rising pump main up the hill in this contract, charging for the same at the contract price, in which the contractors were sustained by the Council. At this time the first steam pump, after twenty years of service, was abandoned. The new pump was started in March, 1846, but gave very poor satisfaction, and would have been condemned had the Solicitor not held that the contractors were not liable for defects in construction. Later new pumps and chambers increased its efficiency.

Another incident of those days will illustrate some of the controversies among the citizens on account of the Water Works. In 1842 Mr. Nicholas Longworth called the attention of the Council to the great importance of a reservoir on higher ground, and offered to sell a valuable site on Mt. Adams for such purpose at $500.00 per acre, which he claimed was about one-fourth its value. This proposition was rejected by the Council for the reason that the price asked was double its value. In 1846 the Council appointed a Committee to confer with Mr. Longworth, and that Committee considered his proposition of two-thirds the price at which he would sell to an individual so unreasonable that they would not trouble the Council with a report, stating that $1,400.00 per acre for ground "too poor to raise sauer kraut was exorbitant." Mr. Longworth, to put himself on record, proposed in writing that the Council should take possession of the site without fixing any price, but should allow him within $500.00

per acre the price at which he sold adjacent ground at private sale, claiming that in five years the property would be worth five times the price he was asking for it, and that he would, at the expiration of that time, report its value to the Council. In less than three years after that time he was selling this property at the rate of from $10,000.00 to $14,000.00 per acre.

After various changes created by the Council in the management of the Water Works, the Legislature passed an act on February 3, 1847, placing the Works in the care of a Board of three Trustees, to be elected annually, and this law remained in force for thirty years.

On September 5, 1849, the Board accepted plans prepared by Mr. T. R. Scowden, who was the Engineer of the Works, for a new reservoir on the hillside and above the old reservoir, the same to consist of two basins of an aggregate capacity of about six million gallons. This reservoir was constructed above ground and entirely of selected and dressed limestone. The east basin was completed in December, 1850, and the west basin in September, 1853, since which time and until quite recently, this reservoir has been in constant service, being until 1875 the only reservoir which the city had then in use. Plates A, B, and C show a view of this reservoir after its use had been discontinued, the stand pipe adjoining and a stone tablet set in the reservoir wall. One view also shows the Front Street Pumping Station in the distance, with its fourteen stacks after it had been permanently shut down. In 1850 Mr. T. R. Scowden prepared plans for a condensing pumping engine of four and a half million gallons daily capacity, which were adopted by the Board in May of that year, and the construction of the same placed in the hands of A. Harkness & Son. This pump was started in February, 1851, and found to be quite satisfactory. Three years later D. Powell & Sons built a duplicate of this pumping engine, which was started in August, 1854, and these two pumps have continued in service, delivering water into Third Street Reservoir until September, 1907, at which time both pumps and reservoir were permanently put out of service by the New Works.

In 1853 the Board employed Professor Locke to carefully examine into the character of the water supply and to submit a comprehensive report thereon and its contamination, if any. The results of his examinations were very satisfactory, and allayed the fears of possible pollution for a number of years.

For the purpose of equalizing the water tax, the Council on February 15, 1860, passed an ordinance, prepared by City Solicitor R. B. Hayes (afterward President of the United States), assessing a tax of ten cents per front foot on all property abutting

on streets in which water mains were laid. Two years later this ordiance was repealed, and the Council, in lieu thereof, assumed the payment of the interest on outstanding Water Works bonds, which was done until December, 1878, since which time the Water Works has assumed this obligation.

On November 15, 1860, Geo. Shield, then Engineer of the Water Works, submitted to the Board plans and an estimate of cost for a twenty-four million gallons condensing pumping engine. These were adopted by the Board, and the contract for its construction was awarded to the Niles Works. This pumping engine was of a very heavy and massive design, and never worked satisfactorily, either in capacity nor in efficiency, and was not used when it could be avoided.

A careful test made in August, 1872, of all the pumping machinery, by Mr. Chas. Hermany, of Louisville, showed that, although the duty of no engine was remarkable, that of the last pumping engine was less than twenty-four million foot pounds per 100 pounds of coal, and not more than two-thirds that of the next lowest duty pump.

In order to meet the demand for water on the hilltops, an auxiliary pumping station was established at Hunt Street, near Liberty, in 1869, the same containing one horizontal pumping engine of one and a half million gallons daily capacity, and in order to provide some storage an iron tank of sixty feet diameter and thirty-eight feet in height, holding over 750,000 gallons, was erected on Mt. Auburn. The consumption on the hilltops increased so rapidly that a second tank was erected in 1871, and in later years a third and a fourth one were added. In 1874 the pump was enlarged, and again in 1879, increasing it to four million gallons daily capacity. A second pump was installed in 1879, and in 1886 a six-million gallons Worthington pump was placed in service.

In 1872 T. R. Scowden prepared designs for two new pumps, each of seven and a half million gallons capacity. These pumps, as well as the last pump designed by Geo. Shield, were planned and constructed to deliver water to an elevation fully sixty to seventy feet above the existing reservoir, through a stand-pipe erected near the reservoir. Some difficulty arose with the contractors constructing the last pumps, and the city was obliged to use their shop and tools for a considerable period and complete the pumping engines at a very greatly increased cost. Both pumps were completed in the latter part of 1874 and placed in service.

In 1865 Mr. J. P. Kirkwood was engaged to make a very thorough survey and investigation, and to submit his recommendations for the future water supply of the city. His plan provided for taking the supply from the Ohio River with subsiding reservoirs and filters located about two miles above the old pumping station, and included

two pumping lifts. The estimated cost of the proposed improvements amounted to over three million dollars.

This plan met with great favor by the majority of the Water Board, while the minority favored the existing Works, and recommended constructing additional reservoirs. The Council approved of the latter plan, and in 1866 authorized the purchase of a large tract of land, now known as Eden Park, for reservoir and park purposes. The site for the reservoirs consisted of a deep ravine enclosed on three sides by steep hills, and necessitated a fill of eighty-four feet in depth at the lower end and a heavy retaining wall 120 feet in height. This work was started in 1866, and was divided into two basins, the upper basin, which was completed in 1872, having a capacity of fifty-seven million gallons, and the lower basin, which was not completed until 1878, having a capacity of forty-three million gallons. The main wall is constructed of stone masonry, is 1,251 feet in length, 120 feet high, 48½ feet wide at the base and 18½ feet at its narrowest point near the top. The division wall between the two basins is 307 feet long, 67½ feet high, 30 feet wide at the base, and ten feet at the top. The two effluent pipes, 35 and 36 inches in diameter, pass out through a brick tunnel 12 feet in diameter, and about 1,100 feet in length. The upper basin was put into service in 1874 on the completion of the new Scowden pumps, and the lower basin when it was completed. The cost of these reservoirs was $1,660,000.00.

On January 1, 1872, Mr. T. R. Scowden submitted plans and estimates for new Works to be located on the Ohio River ten miles above the city, these Works to consist of three low and three high-service pumping engines, each of twenty million gallons daily capacity, of a sixty-inch diameter supply main to four subsiding basins, each of twenty-five million gallons capacity, and of three force mains, each forty-six inches in diameter connecting to a storage reservoir of 300 million gallons capacity. From this reservoir the settled water was to be delivered by gravity through two supply mains, each forty-six inches in diameter and ten and one-third miles long to the Eden Park Reservoirs. The estimated cost of this work was $4,545,143.95. The site, which was known as the Markley Farm, containing 146 acres, was purchased by the city in 1872, for the sum of $22,321.50.

In 1877, on account of the irregular topography of the city, the distribution system was divided into three divisions, each being supplied under a different pressure, the low service being supplied by the Third Street Reservoir, under a head of 172 feet above low-water mark, the middle service supplied by Eden Park Reservoir, under a head of 233 feet, and the high service, supplied by Mt. Auburn tanks, under a head of 492 feet above low water.

In 1879 a contract was awarded for the erection of a steel tank 100 feet in diameter and forty-eight feet high on the top of Price Hill for the purpose of supplying a fourth division, being that of Price Hill, with water. This tank was completed in the fall of 1880, but the tank was not tested nor put into service until late in June of the following year. When the water in the tank had, on the evening of June 29, 1881, reached 39½ feet the tank was totally destroyed by rupture, a section of the plates, 24 x 48 feet in size, being thrown a distance of 100 feet in one direction, while the balance of the walls of the tank was carried from 100 to 400 feet into the opposite direction. From the plates of this tank a steel tank thirty feet in diameter and sixteen feet high was erected for temporary service on Price Hill, the water being delivered into the tank by two small pumps installed in a new pumping station at the corner of Glenway and State Street, near the foot of the Price Hill Incline.

During the years 1878 to 1884 the city many times experienced a scarcity in supply of water, necessitating at times a general restriction in the use of the same. This shortage was caused by the frequent breaking down of the various pumping engines at Front Street Station, which were of such a character that they were referred to by Mr. E. D. Leavitt, Jr., in a paper read at the Montreal meeting of the British Association in 1884 in the following words: "There is probably no greater mechanical curiosity shop than the pumping station in Cincinnati, Ohio, where may be found engines the likes of which have never been erected at any other Works, nor are ever likely to be." This was undoubtedly due to the fact that whenever new pumping engines were purchased, they were contracted for on the design of those who happened to be in charge of the department and were built partly by contract and partly by day labor, and when such pumping engines were completed they were found to be defective in design, expensive to operate, and as liable to get out of repair as the old machinery, especially when for nearly forty years the average term of any one Superintendent of the Works had been not more than two years. In February, 1883 and 1884, it became necessary to shut down the pumping engines entirely for a period of six days on account of the extreme high stage of the Ohio River, which at times flooded the engine-room floor of the Front Street Station to a depth of over six feet. These conditions were a source of constant anxiety, and the Superintendents called frequent attention to the necessity of providing additional pumping machinery and to proceed with the reconstruction of the Water Works at some point along the river above the outlet of the Little Miami River, or of Crawfish Creek at least.

Inability to obtain the necessary funds on account of lack of legislative authority, postponed securing additional pumping engines until February 9, 1885, when a contract for two compound, condensing, beam crank and flywheel pumping engines, each of ten million gallons daily capacity was entered into with Robt. Wetherell & Co., of Chester, Pa., at a cost of $99,000.00. The first of these pumps was erected in place at the Front Street Station by September 3, 1885, and the second was completed in January, 1886. Some little trouble was had in putting each of these pumps into regular service, on account of blowing out of pump joints, the breaking of discharge mains and of steam pipes, and other interruptions.

On the test runs made in November, 1885, the first engine was found to deliver very nearly eleven million gallons of water into Eden Park Reservoir, developing a duty of 109 million foot pounds per 1,000 pounds of steam consumed by the engine. Yet within one year these pumping engines were declared to be "complete failures, and have not and can not be of service until rebuilt upon new plans."

In 1887 a contract was entered into for the construction and erection at Front Street Station of two Worthington vertical duplex pumping engines jointly of twenty-five million gallons daily capacity. One of these pumps was put into service in June, 1888, and the other early in 1889.

Notwithstanding these additions to the pumping capacity at the Front Street Station, it seems the city was no further removed from a possible water famine during the summer months than it had been for over ten years previous thereto, for these last two pumps also seemed to have gotten into bad condition, and in need of very early and extensive repairs.

At frequent periods the supply was so entirely inadequate to meet the demands, that all elevators were ordered off and the consumption restricted in every way.

During 1890, with a population of 297,000 dependent upon the department for its water supply and fire protection, the city, notwithstanding pumping machinery of a capacity equal to 45,000,000 gallons a day, had been added to its main station during the past five years, found itself on the verge of a water famine. In May, 1890, the Board of Public Improvements appointed Chas. Hermany, J. J. DeKinder, Geo. Hornung, and J. M. Robinson as a Board of Experts to report upon the actual condition of each pumping engine and the amount of repair necessary to each, and to state its capacity when put in safe working condition. This Board reported the capacity of the nine pumps at Front Street Station as not to exceed 28,000,000 gallons per day, but when placed in good condition would be equal to 70,000,000 gallons instead. It also recom-

mended that the urgency of the conditions required the installation of at least five auxiliary pumps of an aggregate daily capacity of 14,000,000 gallons until all the repairs were made. In July, 1890, the Commercial Club of Cincinnati appointed a Special Committee to investigate the deficiency of the water supply and to engage competent hydraulic and mechanical engineers and legal counsel to assist them in their investigation and to see that the recommendations of the Board of Experts were properly carried out. This was done, and the Committee, in its very complete report, reflected seriously upon the methods of managing the Water Works in the past.

During the summer of 1890 an auxiliary pumping plant was installed, consisting of six high-pressure pumps of a total capacity of 17,000,000 gallons per day, these pumps being located on incline cars capable of being raised or lowered on three inclined tramways on the river bank to conform with the rise and fall of the river. These pumps were a great aid in relieving the situation, and it was claimed, though they are high-pressure pumps, that they delivered water into Third Street and Eden Park Reservoirs at less cost than the pumping machinery in the station was doing. The usual trouble was also experienced with this installation, in that three of the pumps had their pump ends and piston-heads broken within the first year of their service.

Steps were taken to thoroughly repair and reconstruct all of the pumps at the Front Street Station, which work was completed by 1893. Two new Gaskill pumping engines, each of 6,000,000 gallons daily capacity, were placed in the new high-service pumping station in Eden Park. A new and ornate stand-pipe and tower for this service was also erected on the high ground in Eden Park and connected with the new pumping station on one side and the high service distribution system on the other by means of two twenty-four and one thirty-six-inch mains.

The pumping station at Glenway and State Streets for the Price Hill high service was abandoned and a new station erected at the corner of Sixth Street and Mt. Hope Avenue, and properly equipped for this service with two new Wilson & Snyder pumps. In connection with this service, which was extended so as to also cover the high ground of Fairmount, four steel tanks each thirty feet in diameter and fifty feet high were erected on the site of the tank which collapsed in 1881.

In 1892 an additional pumping station was erected at Gulow and Vandalia Streets, and equipped with direct-pressure pumps to supply the high territory in Cumminsville, located in the northwest part of the city. This service was started on January 1, 1893. In 1895, with a population of 307,500, the average daily consumption is given as over 47,000,000 gallons, with a minimum of 28,768,291, and a maximum of 65,220,702 gallons.

In 1896, by the annexation of the village of Linwood, the city obtained another pumping station and works which took its supply from deep-driven wells. This service was direct to the high ground west of Linwood and to an elevated tank located above this high territory and by reservoir to the lower territory, the reservoir being supplied by overflow from the tank at elevation 473, the water in the reservoir being at elevation 377.

The pressure from the Price Hill tanks being insufficient to serve the people in the Westwood district, another auxiliary pumping station was established on Harrison Avenue, near Robert Avenue, and equipped with a Worthington pump, which took its supply from the Price Hill high-service mains and delivered directly into the pipe system of Westwood at an increased pressure of from forty to forty-five pounds. This station was put into service on February 2, 1898.

The distribution systems of the various districts were extended from time to time, the total length of water mains in use on January 1, 1900, being 386.66 miles, of which over thirty per cent was less than six inches in diameter and over eighty-eight per cent was less than twelve inches in diameter.

The question as to the potable character of the river water was first raised in 1853 and again in 1865, when Mr. J. P. Kirkwood submitted his report recommending that the water be filtered, and that a new site for the works be selected about two miles above the Front Street Station, the estimated cost being $3,038,214.07. In 1872 Mr. T. R. Scowden submitted his plans for new works, which were to be located ten miles above the city on what is known as the Markley Farm, in order to escape local sewage pollution, and that from the Little Miami River. The estimated cost of these works was $4,545,-143.95. This plan did not provide for any filtering of the water. Nothing was done therewith excepting to acquire the Markley Farm.

In 1878 growing danger of polluting the water supply induced the Superintendent to earnestly urge that such action be taken as may be necessary to start the construction of the new Works at the Markley Farm site.

In 1880 the subject of securing a better water supply was again agitated, and C. R. Stuntz, Professor of Chemistry, was directed to make an exhaustive examination of the Ohio River water taken from various points, which resulted in showing that the water taken from the river at the Markley Farm was freer from sewage than that taken from any other point below, except that collected from the Dayton sandbar. In the report for the following year the Superintendent urges that instead of making extensive additions greatly needed to the Front Street Station, that the work of constructing a new plant at the Markley Farm be commenced, the cost of which he placed at

$5,725,000.00. During that year there was considerable alarm about the water supply being contaminated by eddying currents from sewer outlets immediately below the Water Works intake, resulting in the matter being referred for investigation to a committee, consisting of Col. W. E. Merrill, United States Engineer in charge of the Ohio River improvements; Hon. S. F. Covington, President of the Board of Trade; Hon. H. C. Urner, President of the Chamber of Commerce; Hon. Thos. Gilpin, President of the Ohio Mechanics Institute, and Jas. Allison, Esq., hydraulic engineer. This Committee, after careful investigation, reported that they found that there was no contamination of the water supply as charged, but recommended that the dumping of garbage immediately below the mouth of the intake be stopped, and that, on account of the increased impurities in the water, steps be taken to appoint an expert or a commission of non-residents, versed in hydraulic and sanitary science, to examine into various plans for improving the conditions, adding: "We have no plans to submit, and no recommendations for any plans that have been suggested; we only wish to remind you that there is a strong and widely prevalent feeling among our citizens that there is a great necessity for an increased supply of water, and an avoidance of further contamination."

In 1882 the Chief Engineer of the Board of Public Works in reporting upon the subject of sewerage for the eastern district of the city closes the same with the suggestion that the Water Works pumping station be removed to the Markley Farm, thereby avoiding the construction of five miles of intercepting sewers at a cost of two million dollars, which would not insure the Water Works a freedom from sewage pollution, as the Kentucky shore of the river above the Water Works intake is becoming thickly populated, over the drainage of which the city would have no supervision.

In 1888 the agitation for a better water supply brought about the appointment of a commission consisting of Capt. Wm. P. Anderson, Hon. Amor Smith, Jr., and Dr. T. W. Graydon, with directions to thoroughly investigate the "Water Question." This commission, desiring the aid of the very best engineering advice, engaged Dewitt C. Cregier, of Chicago; Henry Flad, of St. Louis; A. Fteley, of New York City; Chas. E. Hermany, of Louisville, Ky., and Professor Chas. B. Brush, of New York City, as a Board of Experts to examine into and report upon the best means of obtaining an adequate supply of pure water for the City of Cincinnati.

The answers to the questions submitted and the conclusions of this Board, based upon a large amount of data carefully collected, including surveys of the territory on both sides of the river, of analyses, observations, experiments on filtration, etc., were strongly endorsed by the Commission and briefly summed up, were as follows:

The location of the intake at the Front Street Station is not a proper one, because the drainage and sewerage from the eastern portion of Cincinnati and from Dayton and Bellevue, in Kentucky, and that from the Little Miami River is a constant source of possible pollution.

It is not practicable nor advisable to improve the present pumping station, because its location between a set of railroad tracks and the river is highly undesirable, because its area is insufficient to permit of proper enlargement or reconstruction, and the risk of fire and for other reasons.

That it is imperatively necessary for the integrity and purity of the water supply of Cincinnati to abandon the present pumping station.

That it is not practicable nor desirable to supply Cincinnati with water from a system of driven wells, because of the hardness of such water and the insufficiency of such supply, even in the Dayton sandbar.

That the Ohio River, above the Little Miami River, should be the source of supply.

That the intake should consist of an inlet tower on the Kentucky shore, with a tunnel leading therefrom, under and across the Ohio River to the pumping station.

That the best location for the pumping station is the Ohio shore between the mouth of the Miami River and the town of California.

That settling basins should be built on high grounds back of California to improve the quality of the water, and

That it is not advisable to construct an intercepting sewer along the north bank of the Ohio River to prevent contamination of the water supply at the Front Street pumping station.

The estimate of cost of the proposed improvements, which did not include any filtration works, but did include pipe lines to Eden Park Reservoirs, was $4,290,000.00, for works which had a daily capacity of 50,000,000 gallons, $5,910,000 for works of 75,000,000, and $6,668,200.00 for works of 100,000,000 gallons daily capacity.

Notwithstanding the Commission urged prompt and speedy action in securing a better and increased water supply, nothing definite was done.

However, the uneasiness regarding the character of the water supply became more general each year, resulting in the State Board of Health, under direction from the Legislature, making careful investigations of the Ohio River water with special reference to its suitability as a public water supply; and in various organizations in the city referring the consideration of the subject to special committees, all of whom reported against a continuation of the existing conditions, urging the city authorities and the Board of Ad-

ministration in particular to take active measures to secure such legislation as will enable the municipality to proceed in obtaining at the earliest practicable time a reasonably pure water supply.

The Engineer's Club, of Cincinnati, in 1892, also considered the subject of the city's water supply, and the views and suggestions of various engineers were presented in well-written papers and discussions, some of them going exhaustively into the history and experience of Water Works in this country and abroad. Every conceivable scheme for a new Water Works was proposed, advocated, and criticised.

Again, on November 25, 1895, the Committee appointed by the Academy of Medicine made an exhaustive investigation, and reported "that our present supply is not only not sufficiently pure for health, but is not up to the required standard — is manifest to all. That it is deteriorating is equally manifest. Several sewers now pour their filth into our water supply, some of them within a short distance of the intake. Others are in contemplation. Other sources of defilement are to be found in the street washings, butcher and tannery refuse, and waste materials from the East End Gas Works and factories along the river. But probably the greatest source of danger is to be found in the pollution of the Little Miami River, caused by the increase of population and industries along that stream." After citing the results of analyses and tests of the water supply made by many authorities at different times and giving other numerous reasons, the report urged that the proper and necessary steps be taken to secure a plentiful and wholesome water supply. Other organizations took similar action, and adopted energetic resolutions, "That the Board of Administration authorize such investigation of the Ohio River water as will effectually determine whether by any practical process this water can be rendered fit for domestic purposes, and whether, if new Water Works should be constructed, how, in what manner, and at what cost the water of the Ohio River can be rendered safe for drinking and other dietetic uses"

On December 21, 1895, the Board of Administration adopted the following preamble and resolutions:

> "*Resolved,* That competent engineers be appointed by this Board to investigate and report upon the subject of enlarging and extending the present Water Works of the city; such engineers to proceed with such investigations, having in view an enlarged capacity of Works, combined with a quality of water which will satisfy the requirements of the most advanced hygienic regulations for potable water; said plans to be developed upon lines which will conform to the modern requirements for economic and convenient operation, durability, and practical utility as a whole as well as in detail, and be submitted with full details as to manner, method of construction, time to be occupied in such construction, as well as its cost, and the capacity and quality of water to be furnished, and the cost of operating after construction; and, be it further

"*Resolved,* That said engineers be directed to investigate and report upon sources of supply other than the Ohio River which may, in their opinion, be capable of meeting the requirements of the city in quantity and quality, and which may be regarded as practical sources for the present and future needs of the city, and worthy of consideration by this Board; and, be it further

"*Resolved,* That John W. Hill, of Cincinnati (Ohio); Samuel Whinery, of Cincinnati (Ohio), and Geo. H. Benzenberg, of Milwaukee (Wisconsin), be and they are hereby appointed as such engineers, and that they be directed to submit the results of their investigations and their report in full for the consideration of the Board not later than March 20, 1896."

Immediately after the Engineer Commission so appointed had commenced its labors, the action of the Board of Administration was attacked and suit was brought by a prominent taxpayer to enjoin the Board and Commission to proceed under these resolutions. The Circuit Court, on appeal, sustained the action of the Board.

On March 20, 1896, the Engineer Commission, after a careful examination into the question of securing a potable water supply, ample for the future needs of the city, submitted to the Board of Administration a very exhaustive report, accompanied by plans and estimates of cost. The investigations which were made had the following objective purposes in view:

1 — A source of supply which at all times will be sufficient for a daily consumption of 107,250,000 gallons, plus such additional consumption as the growth of the city and the wants of the consumers may demand.

2 — An arrangement of pumping stations and pumping machinery, which shall have a capacity of from 80,000,000 to 120,000,000 gallons daily, so arranged as to permit the enlargement of the pumping stations and the increase of pumping machinery, as the future may require.

3 — The adoption of the best type of pumping engines and boilers, and the concentration in each pumping engine of a relatively large capacity, whereby the greatest economy in the cost of fuel and labor will be attained in the pumping of water to the reservoirs.

4 — Such treatment of the water, if necessary, as to make it comply with the requirements of the highest practical standards for purity in water for domestic uses.

5 — An arrangement of the Works, as a whole, and in detail, as simple, efficient, and economic as is consistent with the natural conditions surrounding the available locations for the improvements outlined.

The Commission fully considered the question of obtaining a water supply from the following several sources, viz:

The Cumberland Plateau,	Lake Erie,
Dayton (Ky.) Sandbar,	Ground Water Supply,

The Ohio River.

some of which were clearly impracticable, but were given attention, as they were strongly advocated by some prominent citizens. The Commission, however, like all pre-

vious Investigating Committees or Boards, concluded that the Ohio River was the only proper and suitable source for an abundant supply for the city. Analyses and tests of the water taken from various points along the river above the Front Street Station indicated that the water at no point as far up as the Markley Farm was sufficiently free from pollution to justify its use without being first properly filtered.

The Commission, therefore, presented plans, descriptions, and estimates for improving the City Water Works as follows:

1 — A low-service pumping station and intake pier upon the Ohio side of the river above Five Mile Creek, completely equipped with four units of triple-expansion pumping engines, each of 20,000,000 gallons daily capacity, the building to have space for the installation of six such units.

2 — A double line of 60-inch diameter cast-iron force mains from the low-service pumping station to the subsiding reservoirs.

3 — Six subsiding reservoirs at California, each having a capacity of 50,000,000 gallons.

4 — Eleven sand filters at California, each having a capacity for filtering 6,000,000 gallons daily, and a clear-water basin having a capacity of 20,000,000 gallons.

5 — Three gravity pipe-lines of sixty-inch diameter each from the clear-water basin to the high-service pumping station.

6 — A high-service pumping station west of California of similar dimensions and similarly equipped as the proposed low-service pumping station.

7 — Two lines of rising mains, each sixty inches in diameter, from the high-service pumping station to the high-level distributing reservoirs.

8 — Two high-level distributing reservoirs at Corbly Farm, one mile east of the Little Miami River, each having a capacity of 100,000,000 gallons.

9 — A gravity pipe-line seventy-eight inches in diameter from the high-service reservoirs to Eden Park Reservoirs.

Detailed estimates of the cost of this work at current prices accompanied the report, which, including the cost of the necessary land aggregated to the sum of $6,474,867.06.

An alternative location for the low-service pumping station below the village of California, with the intake located in the river near the Kentucky shore, was referred to, but not favored because the intake and the tunnel therefrom would be outside of the boundaries of the State of Ohio.

On receipt of this report the Board of Administration immediately presented the same, together with a clear and exhaustive statement of the conditions of the city water supply and the necessity for its betterment to the members of the Hamilton County delegation to the LXXII General Assembly of Ohio, then in session, with the request that some decisive action be taken in the Legislature which will "provide for carrying out some plan which will give to the people of Cincinnati an improvement in its water supply, to

the end that they may at the earliest period possible be furnished with an abundant supply of pure and wholesome water."

On April 24, 1896, the General Assembly of the State of Ohio passed the following, known as the Water Works Act, and designated as

AN ACT TO PROVIDE FOR WATER WORKS PURPOSES IN CITIES OF THE FIRST GRADE OF THE FIRST CLASS.

(PASSED APRIL 24, 1896.)

SECTION 1—*Be it enacted by the General Assembly of the State of Ohio,* That whenever in any city of the first grade of the first class the Board of Administration, if there be one, and if not, the Board having charge of the water supply of such city, shall, by a resolution passed by a majority of the members thereof, declare that it is necessary to provide Water Works for such city, if there be no existing Water Works, or shall declare that a material enlargement, extension, improvement, or addition to the existing Water Works of such city is required, if there be existing Water Works of such city, it shall certify such resolution to the Governor of the State, and thereupon it shall be his duty to appoint a Board of Trustees to be known as the "Commissioners of Water Works," composed of five citizens, residents of such city, not more than three of whom shall belong to the same political party. All vacancies in the office of Commissioner shall be filled in the same manner as the original appointment, but so that not more than three of such Commissioners, when such vacancy shall have been filled, shall belong to the same political party.

SECTION 2 — Each of said Commissioners shall enter into bond to the city, with at least three sureties, to the satisfaction of the Mayor as to the sufficiency and of the Corporation Counsel as to form, in the sum of one hundred thousand dollars ($100,000), conditioned for the faithful discharge of his duties; and the bond so taken shall be deposited with the Treasurer of the city for safe-keeping. Each of said Comissioners shall receive as compensation for his services four thousand dollars ($4,000) per annum, which shall be paid out of the fund hereinafter created, or by the contracting parties hereinafter provided for. No Commissioner or person holding appointment under said Commissioners shall be interested, directly or indirectly, in any contract entered into under the provisions of this act. Any Commissioner may be removed for misfeasance, malfeasance, or nonfeasance in the manner provided for the removal of certain officers in Chapter III, Division 4 of Title 12 of the Revised Statutes of Ohio, and the acts that may be passed amendatory and supplementary thereto.

SECTION 3 — The Governor may appoint as one of the said five Commissioners a member of the Board of Administration of such city, if there be such a Board; and if such appointment be made, such Commissioner shall give the same bond as required by Section 2 of this act, and shall receive as compensation the sum of two thousand dollars ($2,000) per annum. The duties imposed upon such Commissioner and the compensation paid to such Commissioner shall be in addition to the duties and compensation of such Commissioner as a member of said Board of Administration; and the duties of such Commissioner, as a member of the Board of Administration as provided by law, shall not be construed as being in conflict with the duties of such Commissioner under the provisions of this act.

SECTION 4 — Said Commissioners shall form a Board, and shall choose one of their number President, and a majority of said Board shall constitute a quorum to transact business. Said Board shall hold regular meetings at such times and places as it may agree upon, and

special meetings under such regulations as it may prescribe; and shall cause to be kept a full and accurate account of its entire proceedings, including an account of its receipts and expenditures, if any; and make a report of such receipts and expenditures annually to the Mayor and Board of Legislation of such city.

SECTION 5 — Said Commissioners are authorized to take up and consider the surveys, plans, and specifications, if any, theretobefore made or devised for water supply, and they may cause such additional investigations, surveys, plans, and specifications to be made as they may deem necessary; and after consideration thereof they may adopt definite plans and specifications providing for the construction of such Works, if there be none existing, or for an enlargement, extension, improvement, or addition to existing Water Works, either within or without the limits of the city or State, including reservoirs, buildings, tunnels, pumping engines, and machinery of all kinds, pipes, and other fixtures, appliances, or facilities, as in their opinion are necessary to secure an abundant supply of pure and wholesome water; and said Commissioners may also determine the location of any such enlargements, extensions, improvements, or additions.

SECTION 6 — Said Commissioners are authorized to acquire by purchase or by the proceedings hereinafter mentioned, on behalf of such city, all real and personal property and franchises necessary for the proper construction of Water Works, if there be none existing, and for the enlargement, extension, improvement, or addition to existing Water Works; and whenever, for such construction or the completion of any part or parts of such enlargements, extensions, improvements, or additions it shall be necessary to use or occupy any street or other public way, space, park, or ground, or any part thereof, belonging to such city, or to cross any stream under the control of the State, said Commissioners may take and use or occupy the same on behalf of the city for such purposes; and whenever it shall be necessary, in the opinion of said Commissioners, to appropriate any land, turnpike, highway, or franchise of any description, or any easement or interest in any of the same, in order to carry out the purposes set forth in this act, either within or without the limits of such city, or whenever for like reason, it shall be necessary, in the opinion of said Commissioners, to appropriate land for the foundations or abutments of piers across any stream within this State, said Commissioners are authorized to commence and conduct, in the name of such city, proceedings therefor, under and according to Chapter 3, Division 7 of Title 12 of the Revised Statutes, and the acts amendatory and supplementary thereto; and no concurrent action of any board or officer shall be necessary; and all the powers with respect to such proceedings that are now vested in any other board or officer shall be vested also in and may be exercised by said Commissioners.

SECTION 7 — Said Commissioners in constructing such works or such enlargements, extensions, improvements, or additions, shall also have power and authority and be governed in respect of contracts as follows:

First — To make contracts, employ such superintendents, engineers, clerks, laborers, and other employees as they may deem necessary, and to fix their compensation; and any of such persons may be removed by a majority of said Commissioners at any time. No contract which said Commissioners shall enter into, or modification thereof, shall be valid until assented to at a regular or special meeting, and concurred in by a majority of all the members, and such assent entered on the minutes of their proceedings.

Second — No money shall be expended on account of plans, specifications, drawings, construction, or equipment of the Water Works herein provided for, or any other expense connected therewith, unless first authorized by said Commissioners, and upon vouchers signed by their President and Clerk, upon the Auditor, or other auditing officer if there be no Auditor, of such city, to be paid by the Treasurer of such city upon the warrant of the Auditor, or other auditing officer if there be no Auditor, out of the funds hereinafter provided. Said Commissioners shall before entering into any contract cause plans and specifications, detailed drawings, and forms of bids to be prepared, and careful estimate of cost to be made; and when adopted by them they may, in their discretion, cause the plans and drawings to be multiplied and printed, by photographing, lithographing, or other suitable process, and the specifications and forms of bids, contracts, and bonds to be prepared, and have the same printed for distribution among the bidders.

Third — All contracts shall be made in writing in the name of such city, and signed by the President and Clerk of said Commissioners and by the contractor. Whenever it becomes necessary, in the opinion of said Commissioners in the prosecution of said work, to make alterations or modifications in any contract, such alterations or modifications shall only be made by order of the Commissioners; and such order shall be of no effect until the price to be paid for the work or materials, under such altered or modified contract has been agreed upon in writing, and signed by the contractor and a majority of the members of said Commissioners; and no contractor shall be allowed or recover anything for work or materials caused by any alteration or modification unless an order is made or agreement signed as aforesaid; nor shall he in any case be allowed or recover more for such work and materials than said agreed price; and if when the Commissioners have ordered an alteration or modification of contract the contractor and the Commissioners can not agree upon the price to be paid for work or materials under such altered or modified contract, they shall submit the matter to arbitration, the Commissioners choosing one arbitrator and the contractor one, and these two a third, and the award of such arbitrators or a majority of them, as to the price to be paid, shall be made in writing and entered on the minutes of said Commissioners, and when so entered shall be binding on both parties.

Fourth — If a contract, agreement, or order made or authorized by said Commissioners be found to violate any of the provisions of this act, it shall at once become void and of no effect; and no money shall be paid or recovered for service rendered or materials furnished thereunder.

Fifth — Said Commissioners shall not enter into any contract for work in the construction and completion of said Water Works system, without first causing thirty days notice to be given in one or more newspapers of general circulation in such city, that sealed proposals will be received for doing the work or furnishing the materials, provided that said Commissioners may procure plans therefor in the manner indicated in Section 5 of this act, and shall not be required to advertise for bids for making or printing the drawings, specifications, and forms of bids, contracts, and bonds.

Sixth — In all cases of competitive bidding, whether in the construction or completion of or furnishing equipments for such Water Works system, no bid shall be received or considered by said Commissioners which covers a patented material, process or device until the person who owns or controls the patent, or has a contract for the exclusive use of such pat-

ented material, process, or device, has entered into a written agreement with the said Commissioners, for the benefit of all bidders, whereby the lowest price shall be fixed at which the owner of such patent or patented article will furnish to said Commissioners, or at which he will furnish to all bidders such patented material, process, or device.

Seventh — All bids shall be inclosed in a sealed envelope and deposited with the Clerk of said Commissioners, and such sealed envelopes shall have indorsed thereon the nature of the same and the name of the bidder; and all bids shall be opened at a regular meeting of the Commissioners, and at an hour to be indicated in said notice. Each bid shall be accompanied with a bond in a sum to be fixed by said Commissioners, signed by sufficient sureties, for the acceptance of the contract, if awarded by the Commissioners; or the bidder may deposit with the Commissioners, in lieu of such bond, a certified check or bank certificate of deposit, payable to the order of said Commissioners, or cash equal in amount to the bond as above required; and in case of refusal by the bidder to whom the award is made to enter into contract according to his bid within such reasonable time as the Commissioners may determine, said bond shall be put in suit, and the amount collected paid into the fund hereinafter provided; or if a check or certificate of deposit or cash is deposited, the amount shall be immediately paid into such fund.

Eighth — Said Commissioners shall enter into contract with the lowest and best bidder, upon his giving bond to such city, with sureties as the Commissioners shall approve, that he will perform the work and furnish the materials in accordance with his contract, and that the sureties agree in advance to such modifications and alterations as may be made by said Commissioners and the contractor, within the limits of the penal sum mentioned in the bond; and on the failure of such bidder, within a reasonable time to be fixed by the Commissioners, to enter into bond with the sureties before provided, a contract may be made with the next lowest and best bidder, and so on until a contract is effected with a contractor giving bond as aforesaid; provided, that the Commissioners may let the work in whole or in parts, and may receive bids for labor and material separately, as it may deem best, and may reject any and all bids. Should a contractor fail, from any cause, to complete the work contracted for by him, said Commissioners shall relet the unfinished part of said work, or complete the same by days' work or otherwise, as may be for the best interests of the city in the judgment of said Commissioners, and shall charge the cost of completion to the contractor.

* *Section* 8 — If said Commissioners should deem it inexpedient or unadvisable to proceed under Section 7 of this act, then in order to provide for the construction of Water Works, if there be none existing, or for the enlargement, improvement, or addition to existing Water Works, said Commissioners are hereby authorized to contract, in the name of the city, with any person, company, or corporation, their successors or assigns, for the construction of such Works, or such enlargements, extensions, improvements, or additions, as an entirety, in accordance with the surveys, plans, and specifications that may be adopted, and for the exclusive privilege of connecting such enlargements, extensions, improvements, or additions with the existing Water Works, and for a lease on behalf of such city of such Water Works, or of such enlargements, extensions, improvements, or additions to the same, from the person, company, or corporation, their successors or assigns, so constructing the same,

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* This section was declared unconstitutional by the Supreme Court, and is therefore eliminated from the act.

upon such terms as may be agreed upon, and may by said contract or lease pledge the income of said Water Works as so constructed and enlarged to secure the payment of the rentals provided in said lease. And said Commissioners are hereby authorized to convey to such person, company, or corporation, their successors or assigns, any property or rights acquired, or which may become necessary to acquire, under the provisions of Section 6 of this act, or authorize the use of any property which may be necessary to enable the said person, company, or corporation, their successors or assigns, to complete the construction or enlargements, extensions, improvements, or additions to existing Water Works, upon such terms and conditions as may be agreed upon; provided, however, that no such lease shall be made for a longer period than forty years, renewable forever, with the right reserved to said city, upon six months notice in writing, at the end of each period of ten years, or at such shorter period as may be agreed upon during the term of said lease, to purchase said Water Works, or the enlargements, extensions, improvements, and additions to the Water Works, under such terms and conditions as may be agreed upon in said contract; and provided further, that in making such contract said Commissioners shall be governed by all the statutes now in force relative to competitive bidding and the making of contracts; and provided further, that if said Commissioners enter into said contract and lease, as herein provided for, then said works shall be operated, managed, and conducted by such city as provided by law.

SECTION 9 — All expenses that may be incurred by said Commissioners up to the time that any contract may be entered into as provided by Section 8 of this act, or until the issue and sale of any bonds hereinafter provided for may have been consummated, shall be paid out of the Water Works funds of such city, by the Board having charge of the water supply of such city, upon vouchers drawn and approved by said Board; but all such sums so paid shall be reimbursed to the said Water Works fund either by the contracting parties hereinbefore mentioned or out of the proceeds of the sale of bonds hereinafter provided for.

SECTION 10 — To provide a fund to pay the costs and expenses contemplated by this act, the said Commissioners are hereby authorized to borrow, from time to time as money may be needed, in behalf of such city, an amount not to exceed six million five hundred thousand dollars ($6,500,000), and to issue bonds therefor in the name of such city, under the corporate seal thereof. Such bonds shall be designated as *"Water Works Bonds"* of such city, shall be signed by the President of said Commissioners of Water Works, and attested by the Auditor of the city, or other Auditing officer if there be no Auditor, and shall bear such interest, not exceeding four per centum per annum, and be payable at such times and places and in such amounts as said Commissioners may determine. Said bonds shall be sold as provided by law, and as a security therefor, upon the sale thereof, a lien shall arise in favor of the bondholders upon the Water Works property then owned and thereafter acquired by such city, except as hereinafter provided for, and upon the net income of the Water Works, and said bonds shall be further secured by a pledge of the faith and credit of such city.

SECTION 11 — The moneys arising from the sale of said bonds shall be deposited with the City Treasurer as a fund to the credit of said Commissioners of the Water Works, and shall be called the "Water Works Improvement Fund;" and of this fund said Commissioners shall be the sole trustees, and shall have full control and disbursement of the same. No part of said fund shall be diverted to any other use or purpose than that specified in this

act. All warrants drawn upon the Auditor, or other auditing officer if there be no Auditor, for payment out of said fund shall designate on their face "for reimbursement" (as provided for in Section 9), "for plans," "for specifications," "for construction," "for equipment," according as they are drawn for the one purpose or the other, and a careful account of the condition of said fund shall be separately kept by the Auditor of said city, or other auditing officer if there be no Auditor.

SECTION 12 — Whenever the Water Works, or the enlargement, extension, improvement, or addition to existing Water Works, are completed as contemplated under Section 7 of this act, control of the same shall be surrendered by said Commissioners to the Board having charge of the water supply of such city; provided, that whenever, in the judgment of said Commissioners, any portion of such improvement is completed so that the same can be surrendered without impeding or embarrassing other portions of said improvements, the same may be surrendered to the Board having charge of the water supply of such city.

SECTION 13 — Whenever any property, both real and personal, occupied and used for Water Works purposes in such city shall not be required for such purposes, by reason of the enlargement, extension, improvement, or addition as herein provided for, the Board having charge of the water supply of such city shall have power, after giving thirty days notice by advertisement in one or more newspapers of general circulation in such city, to sell the same on sealed proposals to the highest and best bidder therefor. And the lien hereinbefore created for the security of the bonds hereinbefore authorized shall be transferred to the proceeds arising from the sale of such property; and such proceeds shall be placed to the credit of the sinking fund hereinafter provided for the final redemption of the bonds issued under the provisions of this act.

SECTION 14—Upon the completion of any Water Works, or the enlargement, extension, improvement, or addition provided for in this act, whether the same be under Section 7 or Section 8 thereof, the term of office of the Commissioners and the employment of their several employees shall cease, and any unexpended funds shall be placed and kept to the credit of the sinking fund provided for by this act; and thereupon the control and management of said Water Works, if constructed under Section 7, shall pass to and vest in the Board having charge of the water supply in such city, and the obligations entered into by said Commissioners under Section 8, if any, shall be assumed and performed by the said Board having charge of the water supply, the expense thereof to be paid out of the revenues of the water department after assuming control of the Works herein provided for. The Board having charge of such Water Works shall not thereafter be permitted to create any debt or liability for any of the purposes for which they are authorized to assess water rents, including all obligations incurred under the provisions of this act, that can not be met and paid from the income of the Water Works department for that year; and all debts created in violation of this provision shall be absolutely void; nor shall the Board of Legislation create any debt or borrow any money for the use of the Water Works of such cities.

SECTION 15 — The interest becoming due on the bonds which may be issued under the provisions of Section 10 of this act shall be paid, pending the construction of said work, out of the proceeds of the sale of such bonds, unless the Board having charge of the water supply of such city agrees to assume the same or any portion thereof, during the construction of such Works, out of the proceeds of the revenues of the water department, and in that

case such Board shall be permitted to do so. The interest becoming due on the bonds which may be issued under the provisions of Section 10 of this act, after the completion of the work herein authorized, and after the control of the same has been surrendered to the Board having charge of the water supply of such city, shall be paid by such Board each year out of the revenues of the water department.

SECTION 16 — For the purpose of providing a sinking fund for the final redemption of any bonds which may be issued under Section 10 of this act, the Board having charge and control of the operations of the Water Works of such city, and the collection of the revenue therefrom, shall make semi-annual payments from the net revenues of such Water Works to the sinking fund, commencing the sixth year after the appointment of the Commissioners provided for in Section 1 of this act, of not less than seventy-five thousand dollars ($75,000) per anuum, until said bonds are paid or an adequate fund provided for the final redemption of the same; and said yearly sums, together with their earnings and other payments hereinafter provided for, shall be invested in accordance with law by the Sinking Fund Trustees of such city, or if there be no Trustees of the sinking fund, then by the Board or officer or officers having charge of the sinking fund of such city, solely for the benefit of the sinking fund for the final redemption of said bonds.

SECTION 17 — No member of said Commissioners shall be individually responsible to any contractor or employee upon any contract or employment made in pursuance of this act, nor to any person upon any claim occasioned by any act or default of any person contracted with or employed in pursuance of this act.

SECTION 18 — The provisions, restrictions, and limitations of Sections 2690*h*, 2690*i*, 2690*j*, 2699, and 2702 of the Revised Statutes shall not apply to the Commissioners appointed under this act in the prosecution of the work or the contracts herein provided for.

SECTION 19 — That Section 2229*a*, passed February 4, 1885 (Vol. 82, p. 50); Section 2229*b*, passed March 21, 1887 (Vol. 84, p. 167); Sections 8417-31 to 8417-35, passed March 2, 1888 (Vol. 85, p. 53); and an act entitled "An act relating to plans and specifications, and constructions and completion of Water Works in cities of the first grade of the first class," passed April 6, 1892 (Vol. 89, pp. 209 to 216), and all other acts inconsistent herewith, be and the same are hereby repealed.

SECTION 20 — This act shall take effect and be in force from and after its passage.

DAVID L. SLEEPER,
Speaker of the House of Representatives.

Passed April 24, 1896.

ASAHEL W. JONES,
President of the Senate.

UNITED STATES OF AMERICA, OHIO,
OFFICE OF THE SECRETARY OF STATE.

I, Samuel M. Taylor, Secretary of State of the State of Ohio, do hereby certify that the foregoing is an exemplified copy, carefully compared by me with the original rolls now on file in this office, and in my official custody as Secretary of State, as required by the laws of the State of Ohio, of an act passed by the General Assembly of the State of Ohio, on the 24th day of April, A. D. 1896.

In Testimony Whereof, I have hereunto subscribed my name and affixed my official seal at Columbus, the 25th day of April, A. D. 1896.

SAMUEL M. TAYLOR,
Secretary of State.

Pursuant to this act, Hon. Asa S. Bushnell, the Governor of the State of Ohio, appointed the following citizens of Cincinnati as members of the Board of Trustees, "Commissioners of Water Works:"

MAURICE J. FREIBERG, CHARLES M. HOLLOWAY,
LEOPOLD MARKBREIT, THOMAS W. GRAYDON,
AUGUST HERRMANN.

The Board met on June 23, 1896, and organized by electing August Herrmann, President; Maurice J. Freiberg, Vice-President, and Thos. W. Graydon, Temporary Secretary. Thos. W. Graydon resigned as Trustee on December 20, 1897, and on December 28, 1897, Wm. B. Melish was appointed by Governor Asa S. Bushnell to fill the vacancy in said Board.

At the first meeting of the Board of Trustees they were notified that two suits would at once be instituted to test the validity of the the act creating the Board, and that it be enjoined from exercising its duties until the validity had been judicially determined.

The cases were tried in the lower courts, and on appeal were finally carried to the Supreme Court of the State, where, on February 2, 1897, a final decision was rendered sustaining the validity of the act, excepting as to Section 8, which section was therefore eliminated from the Water Works Act.

The Board of Trustees thereupon immediately took up the consideration of all the various plans which had been prepared at different times, and as numerous communications and propositions were received by the Trustees having reference to an improved water supply, and particularly relative to water purification, the Board on March 30, 1897, submitted all plans, propositions, and specifications to a Commission of Engineers, consisting of Chas. Hermany, of Louisville, Ky.; M. L. Holman, of St. Louis, Mo.; Clemens Herschel, of Newark, N. J.; Henry Flad, of St. Louis, Mo., and Samuel L. Felton, of Cincinnati, O.

This Commission, after going over the entire ground and studying the propositions very carefully, submitted their report to the Trustees on April 24, 1897. After discussing the merits and demerits of the various plans and reports, they presented the following conclusions and recommendations:

> In conclusion we recommend the establishment of a low-service pumping station, of considerable greater capacity than the main pumping station, at either the Markley Farm site or at the California site, as may appear to your Honorable Board of Water Commissioners advisable, after the consideration of grounds other than those of pure engineering or the control of physical forces. So far as engineering reasons obtain, a successful pumping station can be built and operated at either location.

We further recommend the building of settling reservoirs at the site selected by the previous Commission, in accordance with the plans which your future engineer may, after careful consideration and study, prepare.

We recommend that before proceeding with the designs for and the construction of the filter beds further investigation be made as to the most advisable method of rendering the water of the Ohio River beyond criticism as to appearance or suspicion as to potability.

We recommend that the work of construction of the low-service pumping station and the settling basins be begun as soon as practicable, and the construction thereof pushed with the utmost vigor.

We recommend that a conduit line be built to conduct the water from the proposed clear well of the filter beds to a site for the main pumping station at or near Columbia; this site to be selected by your Chief Engineer after a careful study of the location and requirements of the city as to its main pumping station.

We recommend that this main pumping station be supplied with an emergency inlet that could be used to draw water directly from the Ohio River in cases of great necessity.

We believe, especially in view of our recommendation, that an emergency intake be provided at the main pumping station, that a single line of pipe properly constructed from the settling reservoirs and filters to the main pumping station will be sufficient.

We recommend that two or more lines of delivery pipe be provided from the main pumping station to the city.

As to the cost of the work: In the first place, the estimate made a year ago, at prices then ruling, is higher than it would be today; a year from now it might be different. It is, therefore, impracticable to make an accurate statement as to cost of this work until the contracts are let, when a close approximation may be made. The changes recommended in this report also necessarily modify the estimates and should diminish the final cost. In view of all these considerations, we hesitate to enter into any further discussion of this question beyond stating our opinion that the work can be completed as outlined within the amount originally provided by the act of April 24, 1896.

It must be borne in mind that all the investigations made of this subject up to the present time have been of a preliminary nature. Before any extended work can be undertaken careful instrumental examinations of all the territory to be covered will be necessary, and upon this work so much depends that it should not be unduly hastened. Until this has been done final plans and specifications can not be prepared, or the principal part of the work put under contract.

In the discussion leading up to their conclusions, the Commission presented numerous strong arguments against the Markley Farm site, for the low-service pumping station and in favor of the site immediately below the Village of California, also against providing a high-service reservoir and the location of the high-service pumping station east of the Little Miami River, and also called serious attention to the grave problem of constructing a gravity conduit across the Little Miami River and the Turkey Bottoms, and urged as a proper precaution against interruption the construction of an emergency intake from the river to the intake at the main pumping station to be located west of the Turkey Bottoms.

On May 10, 1897, the Board of Trustees appointed L. F. G. Bouscaren, Chief Engineer, and referred all plans, surveys, suggestions, and recommendations to him for examination and report.

On May 27, 1897, the Board, after full discussion, determined:

1 — That the capacity of the new plant should be so arranged, both as to pumping stations and pumping machinery, that it shall have a daily capacity of from 80,000,000 to 90,000,000 gallons of water, and shall also be so arranged as to permit of the enlargement of the pumping stations and the pumping machinery as the future requirements may demand.

2 — That the site for the low-service pumping station be at California, O.

3 — That no high-level reservoir shall be built.

4 — That the high-service pumping station shall be located on the west side of the Miami River.

The Chief Engineer was directed to proceed with the necessary surveys, and to have suitable borings made to determine the nature of the soil and depth and character of the bed rock from Front Street Station to California.

The following committee of citizens, consisting of M. E. Ingalls, representing the Commercial Club; Henry C. Urner, Optimist Club; W. J. Breed, Board of Trade; Jos. T. Carew, Chamber of Commerce; P. J. Cadwallader, Young Men's Business Club, and E. C. Goshorn, of the Manufacturers' Club, appeared at the Board meeting, and requested permission to attend the meetings of the Board and participate in the consideration of all plans and specifications and of other work arising in connection with their duties, which privilege was granted, and the Committee welcomed to appear and confer with the Board at any time.

On July 30, 1897, G. H. Benzenberg, of Milwaukee, Wis., and Chas. Hermany, of Louisville, Ky., were appointed as Advisory and Consulting Engineers to the Trustees and the Chief Engineer. At this same meeting J. B. Frenkel was appointed Legal Clerk.

On August 21, 1897, the Chief and Advisory Engineers submitted the following report to the Board:

AUGUST 21, 1897.

BOARD OF WATER COMMISSIONERS, CINCINNATI, O.:

Gentlemen—The information supplied by the last and more complete surveys of the territory adjoining the Ohio River, and extending from the Front Street Pumping Station to Markley Farm, being now available, the undersigned beg leave to submit the following report on the progress made by them in the determination of the character and location of the different parts of the new Water Works system.

The recent soundings in the river opposite Markley Farm developed that the maximum depth of water at the lowest stages at said point would not be more than four or five feet, which is not sufficient for an intake; while the borings on the river bank and in the river show that the rock formation, instead of being near the surface of the bank, is found to be about forty feet beneath the surface, and apparently parallel to the steep slope of the

river bank, which removes all especially favorable features this site was supposed to possess. These and other features are found under more favorable conditions at the site immediately below and adjoining the village of California. A depth of twenty feet of water at its lowest stage is found near the Kentucky shore, which will always insure an ample supply of water if taken from said point.

This location is also found to be so near the Kentucky shore that an intake pier will not obstruct navigation at any stage of water. The rock formation is found at a suitable depth to permit the construction of a tunnel, and the site of the pumping station is the most suitable of any between the Markley Farm and the Miami River. We would therefore recommend that the Eastern Pumping Station be located below and adjoining the village of California, between Fourth Street and the river, and that the intake pier be located opposite said site in deep water near the Kentucky shore.

The intake pier should be founded on the bedrock, and connected with the pump well on the Ohio side of the river by a tunnel eight feet in diameter and approximately fourteen hundred feet long, driven through the bedrock. Whilst these constructions will be expensive, they do not involve unusual difficulties or serious risk in their execution and operation.

The pump-well and house should be built long enough to accommodate four pumping engines of thirty million gallons capacity each in twenty-four hours. A plat of ground at least six hundred feet in length of river front by about four hundred feet deep from the edge of the river bank will be necessary for this station.

The question of an emergency intake for the Western Pumping Station has been carefully considered. The large quantity of sewage discharged into the river below the mouth of Crawfish Creek limits the choice of a location for such an intake to the territory between Crawfish Creek and the Miami River. On the other hand, it is advisable, in the absence of any clear-water storage reservoir east of the Miami River, to locate the Western Pumping Station as near Eden Park Reservoir as practicable, in order to reduce the cost and risk of operating long lines of pump mains. It is therefore desirable that the construction of the emergency intake be avoided if it can be dispensed with without danger of interrupting the water supply. Such danger resides principally in the liability of a break in the conduit line across the Miami Valley. The location and style of construction hereinafter recommended for this conduit are such as to render the contingency of a break very remote.

It is therefore recommended that the emergency intake be dispensed with, and that the Western Pumping Station be located on the most available ground nearest Eden Park Reservoir. That site is located between Eastern Avenue and the river, opposite the Torrence Road. The river at this point affords sufficient depth of water for a good coal landing, and the grade of the avenue fronting the property is above high water during the highest floods. The entire depth between the avenue and the river will be needed, with a river front of not less than five hundred feet in length.

The location of the conduit conveying the water from the clear well east of the Miami River to the Western Pumping Station will be in a direct line from the clear well to the east bank of the Miami River, north of and adjoining the C. G. & P. R. R. bridge.

That part of the conduit will be in tunnel, lined with masonry and of circular section eight feet in diameter. The crossing of the Miami River will also be in tunnel of the same size, driven through the bedrock, which is found at that point about thirty-three feet below

low water in the Ohio River. The tunnel will be about thirteen hundred feet long between shafts or wells, connecting with the upper levels of the conduit.

From the Miami River to the Western Pumping Station the line of the conduit will follow closely the alignment of the C. G. & P. R. R.; it will cross said railroad from the north to the south side at Carroll Street, run parallel to and adjoining the Pennsylvania Railroad to Congress Street, where it will cross said railroad to Eastern Avenue, and follow said avenue to a point opposite the pumping station. This part of the conduit will be approximately 18,300 feet long, and will be built of a riveted steel shell eight feet in diameter, lined inside with one ring of brick laid in Portland cement, giving a diameter in the clear of seven feet two inches.

The steel shell will impart the necessary strength and immunity against breakage and leakage; the brick lining will be a permanent protection against inside corrosion.

Before dismissing the subject, it is proper that your attention be called to an alternative location for the conduit.

A glance at the map showing the course of the Ohio River above Cincinnati makes it apparent that the site chosen for the Western Pumping Station can be reached by a straight line from a point on the Kentucky shore opposite the Eastern Pumping Station in a much shorter distance than by the long curve on the Ohio side.

It is entirely practicable to carry the water from the clear well to the Western Pumping Station by a masonry conduit in tunnel, crossing the Ohio River near the Eastern Pumping Station, at a low level through the bedrock; thence through the rock formation of the Kentucky hills, at the elevation of the hydraulic grade, to a point east of the village of Dayton, Ky.; thence across the Ohio River at a low level, through the bedrock to the Western Pumping Station. Such conduits, being almost entirely through rock and built of imperishable material, would have a character of permancy and stability superior to the conduit proposed on the Ohio side, and would probably not cost as much if any more.

Three different schemes for the location of the settling basins and filters have been planned and studied; but, owing to the broken character of the high ground between the hills and the lowlands, sufficient time has not been available for a comparative estimate of cost of the different schemes. As this is one of the most costly and important parts of the proposed Works, we would respectfully suggest that a decision as to a choice between these different plans and locations be postponed until approximate estimates of cost can be made. We are agreed, however, in the opinion that the basins and filters be located on the high ground, and recommend that options be taken for the eventual purchase of all the territory contained between the lowlands on the south, Lick Run and the high hills on the north, the Miami River on the west, and the edge of the plateau on the east.

In all cases a *right-of-way* strip 160 feet wide will be needed, adjoining the western boundary of the village of California, and extending from the tract already described for the Eastern Pumping Station to the Richmond Pike.

The specifications for pumping engines for the Eastern Pumping Station should be further revised and amended before they are presented for final action by your Board. We expect to be able to submit them at an early day next week.

We would respectfully suggest that this strip of land and the tract for the Eastern Pumping Station be acquired with the least possible delay, and that application be made to the

Secretary of War of the United States for permission to build the intake pier as proposed, in order that the construction of the pump well, tunnel, and intake be placed under contract at the earliest date practicable. Respectfully submitted,

G. BOUSCAREN,
G. H. BENZENBERG,
CHAS. HERMANY.

This report excepting that part referring to the character of the conduit was on September 14, 1897, after due consideration adopted by the Board, and in accordance therewith application was immediately made to the Secretary of War for permission to construct an intake pier in the river and a tunnel from there underneath the river bed to the Ohio shore. On October 4, 1897, the following permit was received:

"WHEREAS, By Section 3 of an Act of Congress, approved July 13, 1892, entitled 'An act making appropriations for the constructions, repair, and preservation of certain public works on rivers and harbors and for other purposes,' it is provided that without the permission of the Secretary of War it shall not be lawful to build any wharf, pier, dolphin, boom, dam, weir, breakwater, bulkhead, jetty, or structure of any kind outside established harbor lines, or where no harbor lines are or may be established, in any port, roadstead, haven, harbor, navigable river, or other waters of the United States in such manner as shall obstruct or impair navigation, commerce, or anchorage of said waters; and,

WHEREAS, The Commissioners of Water Works of the City of Cincinnati, O., have applied to the Secretary of War for permission to build an intake pier in the Ohio River, to be connected with the pumping station on shore by a tunnel under the river, for the purpose of increasing the water supply of said city, the location and plan of the structure being shown on the attached drawings:

Now Therefore, This is to certify that the Secretary of War hereby gives permission to the said Commissioners of Water Works of the City of Cincinnati, Ohio, to build an intake pier in the Ohio River, to be connected with the pumping station on the shore by a tunnel under the river, for said purpose, the location and plan of the structures being shown on said drawings, upon the following conditions:

1 — That the work herein permitted to be done shall be subject to the supervision and approval of the engineer officer of the United States Army in charge of the locality.

2 — That said pier shall be kept properly lighted during construction and after completion.

Witness my hand this 24th day of September, 1897. I. T.

G. D. MEIKLEJOHN,
Acting Secretary of War.

On October 13, 1897, the Board of Trustees, in compliance with the provisions of Section 5 of the Water Works Act, adopted the following preamble and resolutions, thereby determining the character and location of the principal parts of the new Works, viz.:

WHEREAS, Under the provisions of Section 5 of "An act to provide for Water Works purposes in cities of the first grade of the first class," passed April 24, 1896 (92 O. L., page 606), the Commissioners of Water Works are authorized to take up and consider the sur-

veys, plans, and specifications, if any, theretofore made or devised for water supply, and they may cause such additional investigations, surveys, plans, and specifications to be made as they may deem necessary; and,

WHEREAS, This Board, acting as such Comissioners of Water Works, did take up and consider the surveys, plans, and specifications heretofore made or devised for water supply, and did cause additional investigations, surveys, plans, and specifications to be made as they deemed necessary with a view to provide for a material enlargement, extension, improvement, or addition to the existing Water Works of this city; such material enlargement, extension, improvement and addition to the existing Water Works of this city having been declared to be necessary by a resolution duly passed by the majority of the Board of Administration of this city, as provided in Section 1 of said act (Vol. 1, page 151 of the Water Works Minutes, June 6, 1896); said Board of Administration having charge of the water supply of the city; and said resolution having been duly certified to the Governor of the State, as provided in Section 1 of said act; and such material enlargement, extension, improvement, and addition to the existing Water Works of the city being also deemed necessary in the opinion of this Board: Therefore

Resolved, That the following definite plans and specifications for the construction of such enlargement, extension, improvement, and addition to the existing Water Works of the city, including reservoirs, buildings, tunnels, pumping engines and machinery of all kinds, pipes, and other fixtures — also the location of such enlargement, extension, improvement, or addition of the same — be and the same are hereby adopted; it being the opinion of this Board that the same is necessary to secure an abundant supply of wholesome water, to-wit:

1 — The construction of an intake pier, founded on a timber caisson carried down to the bedrock, and connected by a shaft with a tunnel leading to the pump pit of the California Pumping Station. (The exact location of said intake pier is shown on the drawing hereto attached, as approved by the Secretary of War on September 24, 1897.)

2 — The construction of a tunnel under the Ohio River, connecting the intake pier with the pump pit of the California Pumping Station.

3 — The construction of a pumping station on a plat of ground adjoining the Ohio River and the village of California at its northwestern boundary, for the purpose of pumping water to settling basins located on the high ground northeast of said village. Said pumping station to consist of a pump pit, a pump house, a boiler house with smokestacks, a coal elevator, a coal shed, and the pumping machinery. The pumping machinery shall consist of three or four self-contained, vertical, triple-expansion crank-and-flywheel pumping engines of thirty millions U. S. gallons capacity in twenty-four hours each, with sufficient boilers to operate them all at the same time.

4 — The construction of an embankment about sixty feet wide on top, adjoining and parallel to the northwest boundary of the village of California, from the river bank to the New Richmond Pike, and the filling to grade of the grounds for the pumping station.

5 — The construction of settling basins on the high ground northeast of California.

6 — The construction of filters adapted to the filtration of Ohio River water at all seasons of the year, after a period of sedimentation lasting about seventy-two hours, said filters discharging into a clear well, and to be of sufficient capacity to filter the entire water supply.

7 — The construction of a clear well having a capacity of about twenty million U. S. gallons, to act as a regulating reservoir between the uniform output of the filters and the irregular demand of the distribution.

8 — The construction of a gravity conduit conveying the filtered water from the clear well to the pump pit of a pumping station at Pendleton.

9 — The construction of a pumping station on a plat of ground about five hundred feet front on Eastern Avenue, between Lumber Street and Queen City Court, and extending from Eastern Avenue to the river, and the filling of said ground to a level grade two feet above high water. Said pumping station to consist of a pump pit, a stand-pipe, a pump house, a coal elevator, a coal shed, a boiler-house with smokestacks, and the pumping machinery.

10 — The construction of one or two lines of pump mains leading from the pumping station at Pendleton to Eden Park Reservoir.

11 — The acquisition, through condemnation proceedings or otherwise, of the right of way and various lots and grounds necessary for the construction and operation of the foregoing described intake, tunnel, pumping stations, settling basins, filters, clear well, gravity conduit, and pump mains; the location, boundaries, and areas of said right of way, grounds, and lots being as shown on the plat hereto attached, which shows also the relative location of said intake, tunnel, pumping stations, settling basins, filters, clear well, gravity conduit, and pump mains.

And be it further resolved, That the Chief Engineer be and he is hereby directed to cause detailed plans, specifications, drawings, and forms of bids to be prepared, including a careful estimate of the cost of the definite plans and specifications above referred to, and submit the same for the consideration of this Board from time to time, in order that the same may be adopted before any contracts therefor are entered into; and to proceed in the preparation of said detailed plans, specifications, drawings, and forms of bids in such order as will, in his judgment, enable this Board in the immediate future to enter into contracts for the various sections of the work contemplated, with a view of securing the lowest prices therefor consistent with good work.

And be it further resolved, That the Legal Clerk of this Board be and he is hereby directed to confer with the Corporation Counsel with a view of immediately instituting the necessary proceedings in the name of the city, as provided for in Section 6 of the act herein referred to, to appropriate any land, turnpike, highway, or franchise of every description, or any easement or interest in any of the same, to carry out the purposes set forth in this preamble and resolution, including also the appropriation of the land necessary for the foundations, or abutments of piers across any stream within this State.

In accordance with the provisions of the statutes of Ohio, the plan showing the proposed source of the water supply and the location of the intake pier, was submitted to the State Board of Health for its approval, which approval was received on January 28, 1898, with the condition that the water supply shall be filtered in a manner satisfactory to the State Board of Health.

At this time steps were taken to acquire all the land required for the new Works by direct purchase where such was possible, or by condemnation proceedings. A table of all the property required by the Board, its purpose, how obtained, and price paid is given in appendix "D," hereto attached. The boundary line between the States of Ohio

and Kentucky being the low-water line along the north bank of the Ohio River, the land necessary for the intake pier and for the tunnel under the river bed is located in the State of Kentucky.

To meet the payments of contracted obligations, the Board in February, 1897, issued bonds to the amount of $50,000.00, which were taken by the Sinking Fund Trustees of the City of Cincinnati, and that amount placed in the city treasury to the credit of the Water Works Improvement Fund.

On August 24, 1897, the Board of Trustees passed a resolution authorizing an additional issue of bonds to the amount of $250,000.00, thereupon a prominent citizen and taxpayer brought suit to enjoin the Commissioners of Water Works from issuing said bonds on the ground "that the issue of said bonds and expenditure of the proceeds thereof by said Board of Commissioners of Water Works at this time would be a misapplication of the funds of the corporation, an abuse of its corporate powers, and would involve the execution and performance of contracts made in behalf of the corporation in contravention of the laws and ordinances governing the same."

On trial, the Common Pleas Court sustained the action of the Board. The table in Appendix "E" shows the amount of bonds issued by the Board from time to time and the amounts received.

On November 3, 1897, the Chief and Advisory Engineers recommended to the Board that, in the absence of sufficient reliable data as to the relative merits of the so-called English and mechanical filtering systems in the purification of the Ohio River water, an experimental filter plant be constructed and operated under the immediate supervision of the Chief Engineer, said plant to consist of settling tanks and filters of sufficient capacity to purify the Ohio River water at the rate of a quarter-million gallons per day under all the varying conditions arising during the year, the information thus obtained to be used by the engineers to determine with a reasonable degree of certainty which filtering system will prove the most practicable and economical in the satisfactory treatment of the Ohio River water.

The erection of such an experimental filter plant in Eden Park below the reservoirs was authorized, and the Chief Engineer empowered to employ a competent and experienced chemist and bacteriologist to conduct the experiments under his direction.

Geo. W. Fuller, of Massachusetts, was engaged to conduct continuous experiments in the operation of the subsidence basins and filters, which work was to include investigations into the composition and character of the river water before and after treatment, bi-weekly reports of progress, and upon the conclusion of the experiments to prepare a full and detailed report of the results of the entire work.

Plans and specifications for the construction of the experimental filter plant were immediately prepared, the work advertised, and on December 14, 1897, the same was let in four different sections, these contracts being the first which were awarded in the progress of the new works. (These and all other contracts are scheduled under Appendix "A.")

On March 28, 1898, the experimental plant was placed in regular and continuous operation until January 25, 1899, when the series of tests were completed. On January 17, 1899, the Board of Trustees granted the application of the Ohio Sanitary Engineering Company, wherein they requested to be permitted to demonstrate at the experimental filter plant their system of filtration for a period of thirty days, the demonstration to be under the direction of said Company and under the supervision of the Chief Chemist and Bacteriologist, who is to include a report of the same with the report of his other work.

A full and complete report of all the operations and observations made at the experimental plant under the direction of the Chief Engineer was submitted to the Board on February 17, 1899, and on June 21, 1899, a report was made on the results of the tests made by the Ohio Engineering Company. These reports with all data and tables were printed in book form and widely distributed. Brief extracts of this report giving a description of the plant together with a resumé of the observations made and of the conclusions arrived at will be found hereunto attached under Appendix "B." After the Ohio Sanitary Engineering Company completed its experiments, all of the experimental filter plant, excepting the laboratory, was dismantled and material sold, report whereof is found in list of contracts under Appendix "A." The laboratory was continued, in charge of Mr. J. W. Ellms, a former assistant of Mr. Fuller, and all cement and other laboratory tests of material used in construction were conducted therein.

On January 12, 1900, the Chief and Advisory Engineers submitted a report (a copy of which is to be found in Appendix "B") containing their conclusions upon the results of the investigations made at the experimental filter plant, closing with the recommendation that for the purification of the Ohio River water the mechanical system of filtration be adopted. After careful consideration, the Board adopted the mechanical system for treating the new water supply.

Later on, before definite plans for the filter plant were prepared, extended experiments were made with small filter units to determine the best method of sand agitation and washing, and how to overcome certain objectionable conditions which were found to exist, when prevailing methods were applied in washing the sand. These experi-

ments were continued with a filter, the sides of which were of glass, permitting a full view of what was taking place during the processes of filtering and of washing, until all the information upon which these filters were designed and constructed was obtained, the principal feature of which is the simplicity and thoroughness of the process of washing the sand under a variable and high head of wash water without disturbing the gravel layers and without the loss of sand.

The first plans and specifications which were prepared in accordance with the plan which was adopted by the Board on October 13, 1897, were those for the pumping machinery for the River or Eastern pumping station, located below and adjoining the village of California. They called for three self-contained vertical triple-expansion crank and flywheel pumping engines, each of thirty million gallons daily capacity, together with the necessary boiler equipment to deliver said quantity of water into the settling reservoirs at about elevation 145 feet above low stage of river water. The specifications also called for the installation of an electric crane of thirty tons capacity, and reserved the right to increase the number of pumping engines to four with the necessary increase in boilers.

On November 30, 1897, proposals were received on fifteen different plans from eight separate bidders, the bids for four pumping engines, boilers, and crane varying from $405,150,000 to $640,000.00 On December 23, 1897, the Board awarded the contract for four pumping engines, the necessary boilers, and electric crane to the Lane & Bodley Company, of Cincinnati, O., at their bid of $514,400.00.

Hereupon plans and specifications were prepared for the intake pier, intake tunnel and shafts, and for the pump pit for the Eastern or River Service pumping engines, all of which were approved by the Board on March 15, 1898. At this time a long communication was received from a Committee of the Taxpayers' Association, wherein, among other things, the Committee "objects to a thirty-million gallon unit" for pumping engines, "as being unwieldy," and to the continuation of the filter experiments (the plant for which had just been completed) because they lacked confidence in the results. It also protested against the building of the intake tunnel under the Ohio River, and the deep level conduit in tunnel from the clear well east of the Miami River to the Main or Pendleton Pumping Station, because such "are not reliable and are dangerous," as well as "impracticable and visionary." It also recommended that the pumping machinery be tested to 300-pound pressure instead of 100 pounds, the maximum working pressures of which would never exceed sixty pounds. Other equally puerile advice was submitted from time to time, with attempts to criticise the action of the Board and the conclusions of your engineers from standpoints wholly unwarranted.

DESCRIPTION OF THE WORK

INTAKE PIER.

The Intake Pier consists of a solid stone masonry structure supported on a timber caisson 57 x 29 feet in dimension, carried down through the sand and gravel of the river bottom into the bedrock to elevation —34.50, 0.00 being datum at 3.5 feet below low stage of water. At the top of the caisson the pier is 55 x 27 feet, tapering upward with a batter of 1 in 24 to an elevation of 83.00 feet above datum, where the same is topped off with a course of coping-stone. The up-stream end of the pier forms a pointed arch, while the down-stream end forms a half-circle. The pier contains two wells (see sheet No. 2), one being the inlet well on the up-stream side, which is 9 x 14 feet in section with its bottom at elevation — 7.50, the other being on the down-stream end, half being circular and half rectangular in section, and forms the upper part of the tunnel shaft. The inlet well has four rectangular ports, each 4 x 6 feet in size, the two on the channel side with the bottom at elevation —5.50, and the two on the shore side with the bottom at elevation + 12.50. The shaft well is also supplied with two ports of the same dimensions, one on the channel, and the other on the shore side of the pier, with their bottoms at elevation—5.50. An opening of 6 x 7.5 feet connects the inlet with the shaft well. Each port and opening is provided with a suitable sluice-gate and screen, those in the inlet well being basket screens, all operated in guides, the gates by hydraulic pressure and the screens by an electric traveling hoist. The screens consist of brass wire cloth of ¼-inch mesh. The outer openings of the ports are protected by heavy horizontal cast-iron grate bars. Means have also been provided for flushing out any sediment in the inlet well through a drain into the river channel.

The pier is built of best Ohio River sandstone, laid in regular courses, rock-faced on the outside, with all inner faces of wells fine pointed and the ports bush hammered. The nosing and coping consist of granite. On the shore side the top of the pier forms the bridge seat for a steel Pratt truss bridge of 320 feet span, which connects the Intake Pier with the Kentucky shore. The bridge has a width of 14 feet, and on the shore end rests upon a masonry abutment near the C. & O. Railway tracks. The bridge is provided with a standard gauge track, and is built to sustain a live load of 600 pounds per running foot, and a concentrated load of eight tons on a four-wheel truck.

The top of the Intake Pier supports a handsome stone building, finished off with a sightly tower on the up-stream end. (See plates 4, 5, 6, 7). This building contains the electric traveling hoist, pumps, hydraulic cylinders, screen car, tools, and other material, and forms the shelter for the men engaged in hoisting, cleaning, and lowering the various screens. At the shore end of the bridge a neat brick building closes the portal. This building is used as a storeroom and a repair shop in connection with the Intake Pier.

INTAKE TUNNEL.

The shaft well of the pier, extended downward, forms the connection between the inlet well and the intake tunnel and below elevation —8.00, consists of a brick-lined shaft of 7 feet interior diameter. At elevation —69.00 the shaft makes a curved connection with the tunnel, the latter extending in a straight line from this shaft to the base of the pump-pit shaft, a distance of 1,430 feet eastward to the Ohio shore of the river, with a descending grade of one in four hundred feet. The pump-pit shaft, which is eight feet in diameter, is also connected with the tunnel by a curve being made by the soffit of the tunnel arching. The shaft is provided with a sump four and one-half feet in depth. The tunnel, which is seven feet in diameter, was excavated through rock. The lining of the tunnel and of the two shafts, as far as these continued in rock, consisted of two rings of voussoir-shaped vitrified brick, backed with concrete compacted into the entire space between the brick work and the rock excavation. (See plate 12.)

Above the rock the pump-pit shaft consists of a steel shell ten feet in diameter, extending through the pump-pit floor to elevation + 109.00. Below the pump-pit floor the steel shell is lined with two rings of brick set on edge.

Immediately above the pump-pit floor, at elevation — 4.50, the steel shell, which consists of plates three-quarters of an inch thick, is provided with four openings four feet in diameter, fitted with flanged cast-steel nozzles, which openings supply each of the four thirty-million-gallon pumps located in the pump pit. (See plate 10.) The pump-pit shaft is also provided with a Wood propeller pump operated at the upper end of the shaft by an electric motor located on a platform in the shaft at elevation 86.50, also with an electric hoist and bucket operated by another motor in the shaft.

The shafts and tunnel also contain an eight-inch water main and an armored electric cable for power and light purposes on the Intake Pier and one for telephone service. The water main is used to supply water under pressure for washing the screens on the pier. It is also provided with Siamese hose connections every ninety-eight feet

of its length in the tunnel, to be used in flushing sediment out of the tunnel into the sump, from where the propeller pump can pump it up and discharge same into the river.

PUMP PIT.

The Pump Pit consists of a circular stone wall resting on a timber caisson 128 feet in diameter. The roof of the caisson consists of twelve solid courses of 12 x 12-inch oak timber closely and solidly drift-bolted together. The roof is supported by a circular wedge-shaped wall of oak timber, the lower edge finishing in a shoe, consisting of 8″ x 8″ x ⅞″ steel angles riveted to a 1″ x 24″ steel plate. The roof and circular wall are stiffened by two sets of oak cross walls three feet wide and extending seven feet below the roof and dividing the space under the roof into twenty-one working chambers, twelve of which were provided with working shafts three feet in diameter, which extended through the roof of the caisson. (Plates 8 and 9.) The central chamber was provided with a circular steel encased opening of ten feet three inches in diameter for the pump-pit shaft to pass through. Passage ways through the cross walls were also provided to afford communication between the various chambers. The pump pit is ninety-eight feet in diameter and eighty-five feet deep, and is formed by a circular stone masonry wall fifteen feet thick at the bottom, where it rests upon the caisson, and four feet thick at the top, the inside face being plumb and fine-pointed. A cylindrical shell of riveted and caulked one-quarter-inch steel plates is built into the masonry wall three feet back from the inner face for a height of seventy feet above the caisson to render the pit water-tight. Sheet No. 3 shows a section of the pump-pit caisson and intake shaft.

At proper elevations arched openings were built through the wall for a twelve-inch drain pipe for the Wood propeller pump and for four forty-eight-inch pump mains, and also for the admission of necessary steam mains. (Plate 11.) At the top of the wall three steel horizontal struts are anchored into the wall and riveted to the steel-pump pit shaft to brace the latter. Opposite the middle strut and in line with the entrance to the engine house a plate girder is built from the wall to the steel shaft, and supports a standard-gauge track, which permits of cars being run into the engine house, the floor level of which is 78.83 feet above city datum, or 5.13 feet above the highest known stage of river water at this point.

The elevation of the ground of the pumping station site was 60.00 feet above city datum, which was filled with compacted earth to elevation 77.00. (Plate 13.) From this site, which is 400 feet square, an embankment fifty-four feet wide on top was constructed eastward for a distance of about 1,600 feet to a connection with the Columbia and New Richmond Turnpike, the elevation of the top of the embankment being

seventy-seven feet for a distance of 1,100 feet, then rising at a 2.5 per cent grade to elevation 96.00 at the Turnpike. (Plate 14.) Both slopes of the embankment and all except the river front at the pumping station site are protected by heavy rip-rap, while the river front at a slope of 3 to 1 is protected by a stone pavement of not less than twelve inches in depth.

EASTERN OR RIVER PUMPING STATION.

The pump pit is enclosed by a circular engine house, built of Bedford stone, upon the walls of the pump pit, and covered with a cone-shaped steel roof and lantern frame supporting a covering of vitrified "S" tile. The interior of the walls for a height of 28.5 feet above the floor level are faced with Tiffany white-enameled bricks, above which, on a projection in the wall, is placed a steel track girder for the rail of a circular electric traveling crane, the inner end of the crane revolving on a turntable placed on the top of the pump-pit shaft. A circular gallery six feet wide with brass railing four feet high is supported around the engine room at the floor level on steel brackets anchored to the pump-pit wall. This gallery is connected with the gallery around the pumping machinery.

A boiler house, 60 x 180 feet on the inside, and an annex building, 54 x 55 feet, inside measurement, connecting the boiler house and the north side of the engine house, are also built of Bedford stone, the exterior of all the buildings being rock-faced and the inside faces being sawed smooth and rubbed. The boiler-house has a steel roof and lantern frame, and the annex a simple steel-roof frame, each covered with vitrified "S" tile. The boiler-house contains rooms with individual lockers for all the employees of the station, also toilet rooms with shower baths and other conveniences.

The annex contains the generators for all the electric current required to light all the buildings and grounds of the Water Works plant near California, and for the power needed to operate all the valves, pumps, and machinery connected with said plant, excepting the main pumping engines and the auxiliary machinery in the boiler-room. The annex also contains the office and tool and store rooms of the station. The floors in the boiler room and the machinery room of the annex consist of concrete, in the toilet rooms of plain red American tile, and in the office and storeroom of matched yellow-pine flooring. The smokestack, located about twenty feet north of and opposite the center of the boiler house, is circular in section, 175 feet high and eight feet internal diameter. It is built of brick upon a circular stone base, which in turn is supported by a concrete foundation thirty-five feet in diameter and eight feet deep. The stack is faced with light buff-colored radial Kittanning pressed brick, and topped with a cast-iron cap.

About thirty feet north of the boiler house a steel coal-storage house, supported on steel columns, affords storage room for seven thousand tons of coal. The coal bin is sixty-nine feet wide by 225 feet long, the lower part consisting of 114 hopper-shaped pockets, each equipped with a coal spout and valve leaving six and a-half feet head room above narrow gauge coal tracks running lengthwise underneath the hoppers. At the west end of the building a double track incline leads from the upper track system above the coal bin and from the hoist house down the river bank to low-water line. The coal is delivered by river in coal barges, unloaded into two-ton steel coal dump cars, which are drawn up the incline and dumped at will into the coal bin. The coal is run out of the hoppers into boiler room charging cars, which are switched into the boiler room by a narrow-gauge electric locomotive, which also handles the ash cars to the waste pit. Plates 17 and 18 show this group of buildings, and Plate 19 shows same during high stage of water on January 23, 1907.

PUMPING MACHINERY.

The pump pit contains four self-contained triple-expansion crank-and-flywheel pumping engines, which take their supply from the pump-pit shaft through the forty-eight-inch openings and discharge through forty-eight-inch delivery mains into two lines of sixty-inch diameter pump mains, laid in the embankment, and through these to the settling reservoirs at elevation 145.00 feet above city datum. These pumping engines are grouped around the shaft, resting upon massive bedplates, 23′ 7″ x 36′ 4″, which are bedded on and bolted to the timber deck of the caisson. The three steam cylinders, which rest upon heavy cast-iron "A" frames bolted to the bedplate, reach 100½ feet above the bedplates, and are the only parts which reach above the engine-room floor level. The three pump chambers of each unit rest upon the bedplate, and are directly under the steam cylinders, each plunger being connected with the piston by means of rods to the cross-head. The plungers are outside packed, and the length of their stroke is eight feet. The valve chambers are separate from the pump chambers, and also rest on the bedplate, the suction-valve deck being below the river level at its lowest stage. Plates 20, 21, and 22 show a view of parts of these pumping engines. The design and spacing is such that every principal part of the pumping engine can be removed and reached by the overhead thirty-ton electric traveling crane without disturbing any other parts of the machinery. Between pumping engines Nos. 1 and 2 and adjoining the pump-pit wall an electric elevator and cab is provided for carrying men from the engine-room floor level to the pump-pit floor, or to either one of the seven engine-gallery levels.

The Wood propeller pump in the shaft has a capacity of 1,000 gallons per minute, and can drain the tunnel and shafts in from eight to nine hours' time, discharging the water and silt deposit in the tunnel back into the river through a twelve-inch pipe, passing through the wall of the shaft and pump pit at elevation 60.00.

The boiler plant consists of four batteries of two boilers each of the Stirling water tube type, equipped with the American underfeed stokers. Each battery of boilers is provided with a superheater, located between the boilers, and so arranged that the boilers can be operated with or without the superheaters. Each double battery of boilers is equipped with a Green economizer, also with a fan engine and fan of sufficient capacity to supply air to all the boilers. Each battery of boilers is capable of furnishing steam at 150 pounds pressure, sufficient to operate each pumping engine at its full capacity under maximum load. These boilers also furnish the steam necessary for operating the electric generators and all auxiliary machinery and for heating the building. A special eight-inch pipe line from the filter plant supplies the boilers and toilet rooms with filtered water.

The electric generating plant, located in the Annex, consists of three units of two 75-kilowatt, 4-pole Crocker-Wheeler direct current generators, directly connected to two gear wheels, which are driven by a DeLaval steam turbine, fitted to operate either condensing or non-condensing. The plant includes two Wheeler condensers, equipped with two double-action suction valveless Mullan air pumps. The condensers and air pumps are located in the boiler room.

In addition thereto a 60-kilowatt Northern electric generator direct connected to a Russell engine is installed in the Annex to furnish current to the electric motor operating the tunnel pump. A seven-panel highly-polished black enameled switchboard, on which all the various instruments are mounted, is also located in the Annex, so as to be within observation from any point near the generators.

PUMP MAINS.

A short distance east of the pumping station, in valve chamber No. 1, the two sixty-inch pump mains are cross-connected and so provided with gate valves as to permit of either one or all of the pumping engines to discharge through either one or both of the pump mains. (Plate 17.) These mains extend along the embankment to the Columbia and New Richmond Turnpike (Plates 15 and 16), from where they ascend in a direct line to the west end of the dam of settling reservoir No. 1, continuing along the dam to the easterly end (Plate 32), turning thence in a southerly direction to the weir houses located between the two settling reservoirs, where, by a system of gate valves

(Plate 33) they can be made to discharge separately or collectively into a receiving basin and over a weir into a distributing basin or through either one of two by-passes to either one of the two reservoirs. The mains from the distributing basin and the by-passes consist of seventy-two-inch-diameter cast-iron pipes ending in each reservoir in an upturned bell-mouthed elbow, located at the upper end of an eighteen feet wide concrete runway and cascade, the cascade extending down the slope to the bottom of each reservoir. (Plate 44.)

The valve pit, receiving basin, canal, weir and distributing basin are all constructed of stone masonry, the weir notch being of bronze and fifteen feet in length. The houses over the valve pit and over the distributing basin are rectangular, and, like all the other valve and shaft houses on the ground, built of hard-burnt brick, faced on the outside with sienna-colored pressed brick, trimmed with buff-colored Rockcastle freestone, and roofed with vitrified American "S"-shaped tiles.

The house over the valve pit contains the valve and motor stands for the various sixty-inch gate valves, and the house over the distributing chamber contains two electric motor-driven centrifugal pumps, each having a capacity of delivering one thousand gallons per minute against a head of 240 feet. These pumps take suction from the distributing chamber below the floor of the house and discharge into a twelve-inch cast-iron main which continues as a ten and eight-inch main back of the curbing around each settling reservoir and coagulation basin. Siamese hose connections placed on these mains from 250 to 300 feet apart permit of quite a number of powerful streams being simultaneously used to rapidly remove accumulated sediment from these reservoirs and basins through the drains provided for that purpose.

The weir at the lower end of the runway between the two houses serves to determine the amount of water actually pumped by either one of the pumping engines.

SETTLING RESERVOIRS.

The two settling reservoirs, serve alternately in removing by quiescent sedimentation of from forty to forty-eight hours duration a large part of the matter which is held in suspension by the river water. This is accomplished by drawing the water from near its surface from one reservoir, while the other is being rapidly filled, and given not less than forty hours for sedimentation, which service is alternated when the water has been drawn down thirty to thirty-one feet. These reservoirs are formed by the construction of two earth dams across the lower end of two branches of Lick Run, which is a tributary of the Little Miami River (see Plates 23, 24, and 25) and by excavations and embankments necessary to remove unsuitable material and to reduce the

irregular surfaces of the ground above the dams to regular slopes and grades. (See plates 40 and 41.) The entire interior surfaces of the reservoirs thus formed have been covered with a blanket of rolled, selected clay not less than three feet thick. A stone curb one foot thick and three feet deep is set, with its top at elevation 145.50 around the upper end of the slope of each reservoir. Above elevation 109.00 the finished surfaces of the slope grading are covered with a twelve-inch layer of crushed stone and gravel mixed with sand. Upon this layer of stone and upon the finished grading below elevation 109.00 a six-inch layer of compressed Portland cement concrete is spread and covered with a smooth coat of Portland cement mortar (Plates 42 and 43). This layer of concrete is covered with a mixture of grade "D" and "L" of California refined asphalt, having not less than ninety per cent of bitumen soluble in rectified carbon disulphide. The asphalt was applied hot in two coats, each not less than one-eighth of an inch thick, a layer of burlap being stretched over the first coat before the second was applied. As the second coat was applied the same was covered with a layer of vitrified brick laid flatwise, breaking joints, herring-bone fashion, with one-quarter-inch joints between bricks (Plate 54). The brick became imbedded in the asphalt and the joints were thereupon thoroughly filled with grout, consisting of two parts fine sand and one part Portland cement.

The concrete is laid in hexagonal sections, with sides twelve feet in length. The joints between sections are three inches deep, three-eighths of an inch wide on top, and are completely filled with asphalt. Above elevation 109.00 half-inch expansion joints are provided every seventy-five feet in the brick layer at right angles with the curb, and are filled to a depth of two and a-half inches with rubber asphalt. The bottom of the reservoirs dip from elevation 108.50 at the southerly ends to elevation 89.00 at the floating-tube piers back of the dams at the northerly ends of the reservoirs. The water enters each reservoir over the cascade, and is taken out through two steel-riveted floating tubes (Plate 45) four feet in diameter, which, by means of swinging elbows, connect with the two five-feet diameter cast-iron effluent pipes, which pass down through the masonry pier into a brick archway. This archway, which is sixteen feet in diameter, passes under the dam at elevation 60.00, and terminates in a brick shaft outside of and at the foot of the dam. (Plates 34 to 39.) The shaft is eighteen feet in diameter and rises to elevation 98.00, above which it terminates in a circular brick shaft house. The effluent pipes pass through the archway, up through and out of the shaft at elevation 93.00 where they connect with each other and with two like effluent pipes from the adjoining reservoir. Gate valves on these effluent pipes at the bottom of the shafts and on the connections outside of the shafts permit of water being drawn through either one

or all of the floating tubes and of being supplied through either one or both of the five-feet cast-iron mains which convey the settled water to the Head House of the Filtration Works. In front of the Head House these mains connect with two like mains which branch off from the pump mains where these cross the Columbia and New Richmond Turnpike. This arrangement permits of water being delivered from the pumps direct to the Filtration Works without the same passing through either reservoir.

Provisions are made for washing the accumulated sediment out of either reservoir by means of large effective hose streams, which cut up and carry the mud to four drainage outlets in the bottom of each reservoir, dispersed nearly equal distances apart, these outlets being connected to sixteen, twenty, and twenty-four-inch cast-iron drain pipes laid in the clay blanket under the bottom of the reservoirs, the drain pipe passing as a thirty-inch cast-iron main through the archway and out at the bottom of the shaft to a paved ditch in the ravine leading to Lick Run. Mud valves over the outlets, operated by hydraulic pressure from near the reservoir curb and a gate valve at the bottom of the shaft control the draining and washing of the reservoir.

An overflow connection fifteen feet wide and ninety-two feet long between the two reservoirs prevents the water in either reservoir from rising above elevation 142.50. The available capacity of the two reservoirs above elevation 110.00 is 330 million gallons, that of reservoir No. 1 being 157.5 million, and of No. 2 being 172.5 million gallons. (Plate 47.)

A finished macadam roadway seventeen feet wide, bordered on the inside by a three-feet wide strip of sod and on the outer side by a suitable paved gutter, affords a splendid drive around each reservoir, revealing many picturesque views. The slopes outside of the driveway have been trimmed and sodded, and add to the general appearance of the grounds.

FILTRATION PLANT AND CLEAR-WATER BASIN.

As the Filtration Plant is the special and most essential feature of the new Works, it and its operation will be described in greater detail than any other part or section of the same.

The Filter Plant and Clear-Water Basin are located between Settling Reservoir No. 1 and the high ground west thereof, and the Little Miami River, the new location of the Columbia and New Richmond Turnpike dividing the same. The Filter Plant consists of three coagulation basins, a head house, filter house, and chemical house (Plate 65), also of a wash-water reservoir and the clear-water basin, together with the necessary piping, valves, and valve houses.

The head, filter, and chemical houses form a continuous building 137 feet by 629 feet (Plate 66), the head house fronting south on the C. & N. R. Turnpike. The coagulation basins also front on the turnpike, and are east of the head and filter house, No. 1 being furthermost and No. 3 nearest to the Filter House. The capacity of Basins Nos. 1 and 2 are each 10.25 million and of No. 3 is 2.16 million gallons.

The clear-water basin is located north of the coagulating basins, and has a capacity of 19.6 million gallons. All of the walls of these basins except the dividing wall between coagulating basins 1 and 2 (see Plate 50) are made of rolled embankments, with a 2 to 1 slope on the outside and a 1¾ to 1 slope on the inside. The outer slopes are sodded and the inner slopes and bottoms are covered and protected by a revetment like that used in the settling reservoirs, consisting of clay, broken stone, concrete, asphalt, burlap, and brick, excepting that on the bottom of the clear-water basin, instead of the layer of brick, a layer of concrete is placed over the asphalt in the form of inverted groined arches, forming pier bases for future columns, should it be found necessary to cover this basin with a roof. A dividing wall between basins 1 and 2 is buttressed and consists of concrete suitably re-enforced with steel rods. The maximum depth of these basins, except coagulation basin No. 3 is 23.5 feet below high water, and in No. 3 is 17.5 feet. The coagulation basins are each provided with two mud valves and outlets, connected to a twenty-four-inch cast-iron drain pipe leading to a branch of Lick Run. These valves are operated by hydraulic pressure from the top of the embankment, and are also equipped with four way-cocks, by means of which the accumulated sediment around the valves can be cut and removed if found necessary to do so to operate them. (Plate 55.)

In the clear-water basin the slopes on three sides terminate at a depth of eight feet below high water in a vertical, concrete wall, the inlet conduit constituting the wall on the west side. (Plate 71.) On the east side the outlet conduit is below the bottom of the basin and at the foot of the full slope. The bottom of the basin slopes for a distance of about fifty-five feet from each wall towards the center, from where it dips at a very slight grade towards the outlet conduit. This is connected to the shaft at the upper end of the gravity tunnel by two sixty-inch cast-iron pipes, controlled by gate valves, and uniting into and by an eighty-four inch "Y" branch with the shaft at elevation 67.00. In addition to this connection there is a sixty-inch cast-iron main from valve chamber "F" to the shaft which connects the filter effluent pipes direct with the gravity tunnel, thus by-passing the clear-water basin.

The head house, chemical house, filters, and filter house, excepting the outer walls, are constructed entirely of concrete. The outer walls are of brick with stone trim-

mings, and the partitions are of plaster of paris blocks. The outer face of the walls are of sienna-colored pressed brick, and the inner side of the filter-house walls are faced with white Kittanning pressed brick. The roofs of these buildings are of re-enforced concrete, covered with a heavy coat of hot roofing pitch and clean, screened gravel.

The head house contains the apparatus for controlling the pressure as well as flow through the six thirty-six-inch branch connections which convey the raw or settled water from the two sixty-inch mains to the circulating chamber, where the first chemical, in the form of a solution of sulphate of iron is injected into the raw or settled water. It also contains the venturi meters with indicating and recording apparatus (Plate 67), the wash-water pumps, the refrigerating machine, and the storeroom, also the general office and office of the Superintendent, also lavatories and laboratories, which consist of two chemical and one bacteriological laboratory and a preparation room. The chemical house is a two-story building and contains the machinery for the preparation of the solution of lime and iron, for receiving and handling the chemicals, also the room for storing the same. It also contains the rate controllers and the boilers used for heating the buildings and for heating the water used in slaking the lime. A circular chimney ninety feet high and forty-two inches internal diameter is located about fourteen feet north of the chemical house.

The filter house, located between the head and chemical houses, contains the twen-eight filters, each consisting of two sections, 14 x 50 feet in the clear, having a rated capacity of 4,000,000 gallons per day. (See Plate 63.) It also contains the pipe galleries, pipe chambers, and the sampling and filter indicating apparatus and the switchboards for operating the several valves of each filter. In addition to these buildings there are three valve chambers, built of re-enforced concrete, which are located beneath the ground, and five valve and two shaft houses, the superstructure of which consists of brick walls faced on the outside with sienna-colored pressed brick, trimmed with stone and terra cotta, and covered with red American "S" tile roofs. These each contain the motors and motor stands and switchboards for operating the sluice and gate valves controlling the flow of water at these points.

The settled water from the reservoirs or the raw water from the pump mains is conveyed from either one or both of the sixty-inch mains through six thirty-six-inch branch connections to the circulating chambers in the head house. An electrically-operated thirty-six-inch gate valve and two twenty-eight-inch pressure controllers in the head house control the volume of flow and the pressure in each thirty-six-inch branch. These are located in a concrete chamber in the basement into which the controllers discharge. The purpose of the controllers is to automatically maintain the water in the

head house and coagulating basins at about elevation 109.50 to 110.00, overcoming a head from the settling reservoir varying from 0 to 32 feet.

As the water passes through either one or both of the circulating chambers, the first chemical, in the form of a solution of sulphate of iron of required strength is injected into the same through two two-inch pipes opening into each chamber. The solution is brought from the chemical house through two lines of three-inch cast-iron pipes laid through the pipe gallery of the filter house. Either one of these lines can be put out of service and cleaned by flushing with filtered water under a head of forty feet.

From the circulating chambers the water flows through one or two sixty-inch venturi meters, which measure all the water passing to the coagulation basins, and indicate upon dials as well as record upon charts, located upon the ground floor of the head house, the rate at which the water is passing out of the head house to valve chamber "B," located about thirty-five feet east thereof and at the southwest corner of coagulation basin No. 3. This information, constantly attainable, permits of regulating the rate at which either chemical should be applied. Provision is made by a thirty-inch branch from one of the sixty-inch mains in front of the head house to both lines of sixty-inch pipes between the head house and chamber "B" to by-pass either settled or raw water to the coagulation basin up to a rate of 70,000,000 gallons per day, thus permitting the thirty-six-inch piping entering the head house to be drained for examination and repair without interfering with the operation of the filter plant.

At the bottom of this chamber the solution of lime of necessary strength is admitted through a twenty-four inch opening, becoming mixed with the water as it passes on through an eighty-four-inch diameter steel conduit to basin 3 or to valve chamber "C," which is located on and at the south end of the dividing wall between coagulation basins 1 and 2. The lime solution is brought from the saturators in the chemical house through a twenty-four-inch pipe laid along the west side of the buildings to and in front of the head house and thence east to the bottom of chamber "B."

The steel conduit is laid in the basin embankment, and is encased its entire length in concrete. A similar conduit passes from another division in valve chamber "B" along and under the upper part of the south slope of basin No. 3 to serve either as an inlet or outlet pipe to that basin. This conduit is fitted with six thirty-six-inch cast-iron nozzles, which open flush with the paved slope at elevation 106.00. (Plate 51.) A third conduit of like construction is laid along the west side of basin 3, connecting this division of chamber "B" with the outlet division of chamber "E," located at the northwest corner of basin 3. By means of four eighty-four-inch electrically-operated sluice valves, water may be passed through either of these conduits. Ordinarily the water is

conveyed to chamber "C," where it passes down and out into either one or both eighty-four-inch re-enforced concrete conduits which connect with chamber "C," and are located on the bottom of basins 1 and 2 at the foot of the south slope. These conduits are provided at their top with twenty-one twenty-inch cast-iron "T" outlets (Plate 52), the tees set in line with the conduits and at elevation 94.50. The water passing through these outlets gradually ascends and crosses over to the north side of the basins, passing out at elevation 106.00 through twenty-one twenty-inch cast-iron nozzles (Plate 53) into an eighty-four-inch steel conduit to valve chamber "D," located at the north end of the division wall between basins 1 and 2. From this chamber the coagulated water passes through another eighty-four-inch steel conduit to chamber "E," and thence through both or either one of two sixty-inch influent pipes direct to the filters in either the north or south half of the filter house, or it passes from chamber "E" to basin 3 and chamber "B" back to chamber "E," and then to the filters. While passing through chamber "E" the water may be given a secondary treatment with either one or both chemicals. Electrically operated sluice and gate valves in these various valve chambers permit of all the water being passed through either one of the three coagulation basins to either the north or the south half of the filters, or to both, or through all the basins, or through either Nos. 1 or 2 in combination with No. 3, or it may by-pass them altogether, as may be found necessary or desirable, and affords, at the present average rate of consumption a period of from one to eight hours for coagulation and sedimentation, with possibly a secondary treatment in basin 3, if necessary. It is not intended to have complete sedimentation take place in the basins, as it is desirable and necessary to have the water, when reaching the filters, still contain a small amount of coagulated material to form the gelatinous film on the surface of the sand in the filters to serve in retaining the remaining bacteria and all other matter in suspension, a very large percentage of these being already removed by the coagulation and sedimentation which takes place in the basins.

By means of a sixty-inch gate valve in chamber "D" the water may be conveyed from the basins directly to the inlet shaft at the upper end of the gravity tunnel, thus by-passing the filters and the clear-water basin. This arrangement is only to be used in cases of emergency. Provision is also made by an overflow in chamber "D" to prevent the water in basins 1 and 2 from rising above elevation 110.00. A thirty-inch drain from the overflow chamber carries the water to Lick Run. The basins are periodically cleaned by means of a number of one and one-quarter-inch hose streams delivered at a pressure of 100 pounds per square inch from an eight-inch main laid around the basins. This main is supplied by the centrifugal pumps at the weir house of the settling reser-

voirs, and has three siamese hose connections for each basin. Each basin has two twenty-inch drainage openings, controlled by hydraulic-operated mud valves. The bottom of the basins slope toward these openings with a two and one-half per cent grade. The sediment is carried to Lick Run by means of a twenty-four-inch drain laid under all the coagulation basins.

The water, in leaving chamber "E," passes through two lines of sixty-inch mains, which enter the east side of the filter house through the central gallery, branching to the north and south in the longitudinal pipe gallery, located between the filters, the same being reduced to thirty inches in diameter at the end of each line. Each filter is supplied from these influent mains by a twenty-inch branch, controlled by a valve. The water enters a central channel or gutter, which divides each filter into two equal sections, and then flows through six openings into each half of the filter. The water passes through the filters, the construction of which is shown on sheet No. 7 (see also Plates 60 and 61), at a uniform rate of about 125,000,000 gallons per acre per day, and is collected in the manifold piping in the pipe chambers underneath the filter (Plates 56, 57, 58, and 59), and conveyed to the two effluent mains which begin at the terminals as thirty-inch mains and pass out of the filter house as sixty-inch mains, located under the influent mains in the pipe and central galleries. These mains convey the filtered water to valve chamber "F," located at the southwest corner of the clear-water basin, the water passing at elevation 93.50 over a weir into the eighty-four-inch inlet conduit located along the west side of the clear-water basin, or through a sixty-inch main laid from chamber "F" along the south side of the clear-water basin direct to the inlet shaft of the gravity tunnel, thus by-passing the clear-water basin.

The rate of filtration is maintained constant by a rate controller at the outlet end of the effluent piping of each filter. Only a sufficient number of filters are run to meet the average daily needs, and their period of operations between washings varies from six to twenty-six hours, and occasionally as high as fifty hours, according to the condition of the coagulated water.

The head necessary to pass water through the filter medium at the rate of 4,000,000 gallons per day per filter of 1,400 square feet area amounts, when the filter is clean, to a little over two feet, and as the difference of elevation between the water coming on to the filters and that going out of the effluent mains varies from twelve to fourteen feet, nearly all of that difference may be utilized in passing water at the constant rate through the increasing deposit upon the sand until the total loss of head has become twelve feet, when the filter must be cleaned and the accumulated deposit be removed by washing. This is done with filtered water and by reversing the flow through the filters

at a rate from seven to ten times as great as the rate of filtration, or at an upward rate of from 1.80 to 2.50 feet per square foot per minute, the dirty water being carried off by the lateral gutters to the central channel or gutter from where it passes out at the bottom through a thirty and thirty-six-inch drain pipe to the Little Miami River. To bring about a thorough washing of the sand, the water is admitted beneath the strainer system under a pressure of about six pounds per square inch at that point.

The process of washing is divided into two periods, the first lasting from one-half to one minute, admits the wash water under about half the above pressure, which lifts the mud layer from off the sand without disturbing the latter, while during the second period the wash water is admitted under full pressure for from three to five minutes, which, without disturbing the gravel, brings the entire sand bed above the screen into complete flotation, yet not to such an extent as to have any of the sand carried off with the wash water.

The wash water is supplied through a thirty-six-inch main in the pipe gallery from a covered concrete reservoir, located about 400 feet south of the head house on the high ground near settling reservoir No. 1. It has, at elevation 150.00, a capacity of 180,000 gallons, and is kept supplied by two electrically-operated centrifugal pumps, each of which has a capacity of 2,500 gallons per minute. These pumps are located in the basement of the head house, and take their suction from a well under the floor, which is supplied with filtered water from the effluent main in both the north and south half of the filter house. They are automatically started and stopped by float switches at the reservoir, so that the latter is being constantly kept full. This reservoir supplies the boilers and toilet rooms at the River Pumping Station through an eight-inch main; it also supplies the laboratories in the head house, the boilers in the chemical house, the water needed for the sulphate of iron solution, and the milk of lime. The water used for washing the filter passes through a thirty-six-inch venturi meter, and the rate of flow is indicated upon a twelve-inch dial revolving once each half-hour.

During the operation of a filter, the valves on the influent and effluent pipes only are open. When a filter is to be cleaned, the valve on the influent pipe is closed, and the water drawn down by filtering until there is but two feet of water on the sand, when the valve on the effluent pipe is closed. The valve on the drain pipe is opened, and the water in the central channel or gutter drained off, after which the washed water is admitted in the manner above described. This process of washing is very thorough and complete, and no other or additional means for cleaning the sand bed are needed nor provided. A small amount of the sediment is allowed to remain in the water at the close of the washing so as to at once form a film over the sand bed on the admission of

the coagulated water. Samples taken from the effluent immediately after the filter has been replaced into service show as good bacterial efficiency as at any time during the run of the filter. After a filter has been washed, the various valves are closed and opened in reverse of the former order. These valves are operated from a switchboard common to each filter. (Plate 64.) The opening and closing of the valves is started by the throwing of a switch, but the current is automatically cut off by a limit switch as the valve approaches its limit of travel, at the same time lighting a lamp which indicates the position of the valve. The entire operation of cleaning a filter and of returning the same into service requires from thirteen to fifteen minutes.

The filtered water, after entering the inlet conduit of the clear-water basin passes upward through six thirty-six-inch circular openings into the basin, passing thence over to the east side of the basin, where it passes out through fourteen twenty-four-inch circular openings in the top of another eighty-four-inch re-enforced conduit built below the bottom of the basin. The south end of this conduit is connected to the inlet shaft of the gravity tunnel by two lines of sixty-inch pipe converging into an eighty-four-inch "Y." A twelve-inch connection to one of the sixty-inch lines of pipe in valve chamber "G" permits the clear-water basin to be drained, while the filtered water enters the shaft through the sixty-inch by-pass. The chemical house contains six lime-slaking tanks, four lime saturators, five iron-solution tanks, a boiler room, a car room for unloading, and elevators for bringing the chemicals to the second or operating floor.

The only chemicals used are crushed lime and sulphate of iron, and are delivered by the manufacturers in bags of 100 pounds each, and storage room is provided both on the first and second floor, the bags being raised to the second floor by two electrically-operated sack elevators. The water for the iron solution and the slaking of the lime is brought in from the wash-water reservoir, while that for the lime saturators is obtained from the sixty-inch mains in front of the head house through a twenty-four-inch main laid along the west side of the filter plant. This water is delivered under the head of the pump mains or of the settling reservoir while the water is above elevation 118.00, and the flow in the saturators is maintained uniform by rate controllers.

The water used for slaking the lime is metered and previously heated to 140° F. The lime is dumped at proper intervals in 100-pound doses into the steel slaking tank under a steel hood, from the top of which a twelve-inch-diameter duct leads to an exhaust fan, which is automatically operated by an electric motor by the opening of the door of the hood, thus preventing any lime dust from entering the room (Plate 69.). The water and lime are mechanically agitated by rake arms, propelled by electric motors, at the rate of eight to ten revolutions per minute, and then flows as a ten-per-cent

milk of lime down into a sixteen-inch pipe which supplies the saturators after leaving the rate controllers. The mixed liquid passes downward through a pipe in the center of the saturator and rises slowly upward on the outside, passing out over a weir at the top of the saturators as a lime-water solution into a channel, from where it flows by gravity through a twenty-four-inch pipe line to the bottom of valve chamber "B." An eight-inch pipe line to valve chamber "E" permits a second application of lime solution at that point if found necessary to perfect coagulation. A stirring apparatus in the bottom of the saturator, operated by an electric motor on top, prevents the lime from depositing at any time. The iron solution is prepared by dumping a bag of sulphate of iron into an opening in the floor (Plate 70), which communicates with a twelve-inch pipe immediately below a bronze propeller, which is operated by a one-quarter horse-power electric motor on the floor. The twelve-inch pipe passes down through the center of the re-enforced concrete tank, which is twelve feet in depth and five feet in diameter, and the propeller, operating at a speed of about 350 revolutions per minute, forces the water upward through the pipe and downward between the pipe and the walls of the tank. The iron dissolves very rapidly, and is carried by gravity from three of the tanks through one of two three-inch pipe lines laid through the pipe gallery in the filter house to the head house, where it is injected through an iron grid into the settled water in the circulating chambers. Another three-inch pipe line leads from the other two tanks to chamber "E" in order to render a secondary application possible should it be required.

As the required strength of these solutions must continually vary with the constantly changing character and condition of the settled water, this variation in the solutions is brought about by regulating the intervals between the time of dumping 100 pounds of one or the other chemicals into the stirring tanks while a constant and uniform flow of water through these tanks is being maintained. A systematic and accurate regulation is made possible by the striking of a gong for each chemical at intervals, controlled by a clock and contact disks so designed that the intervals for each may be made to vary all the way from three and a-half to ninety minutes in time. Upon the determination of the strength of the solution of either chemical required, the inserting of the proper contact disk will, by means of the gong, direct the laborer to empty the bag at the proper moment to obtain the desired results.

GRAVITY CONDUIT.

From the inlet shaft, near the clear-water basin the filtered water is conveyed by gravity through a brick tunnel seven feet in diameter and 22,264 feet in length to the lower or outlet shaft in the rear of the main pumping station on Eastern Avenue at the foot of Torrence Road. Both shafts are ten feet in diameter, the top of the inlet shaft being at elevation 112.00 and that of the outlet shaft 140.00. The elevation of the bottom of the tunnel at the upper end is — 67.60, while at the outlet shaft it is — 78.75.

These shafts consist of riveted steel shells twelve feet in diameter, made of one-half and three-quarter-inch plates, lap-jointed above and butt-jointed with inside cover plates below the surface of the ground, and for the inlet shaft extends down into the rock at elevation — 33.00, and for the outlet shaft down to elevation + 19.00, below which points the shafts consists of two rings of voussoir-shaped vitrified shale brick, backed with cement concrete, the diameter of the brick lining being ten feet. This lining is carried up in the case of the inlet shaft to elevation 98.00 and of the outlet shaft to elevation 90.00, at which points the brick work is covered with a cast-iron hood fastened to the steel shell.

The tunnel consists of two rings of voussoir-shaped vitrified shale brick, backed with not less than six inches in thickness of cement concrete, backed solidly against the rock faces, filling out completely the spaces between the rock and the brick lining. The tunnel is seven feet in diameter, and slopes towards the outlet shaft at a grade of one in two thousand.

MAIN PUMPING STATION.

At elevation 43.50 a seven-feet diameter cast-iron pipe connects with the outlet shaft (Plate 76), the pipe passing through a brick archway twelve feet in diameter, under the boiler house to the inside of the basement or pump pit of the Main Pumping Station. Immediately on entering the pump pit, the seven-foot pipe branches (Plate 77) out into a supply pipe six feet in diameter for the group of low-service pumping engines and a supply pipe of five feet diameter for the group of high-service pumping engines. These supply pipes are laid in an open concrete trench nine feet in width along the south or rear wall of the pump pit (Plate 78), and between it and the engine foundations. They are respectively provided on top with eight thirty-six inch and eight twenty-four-inch flanged openings to supply four pumping engines in each group.

The site of the Main Pumping Station on Eastern Avenue is nearly opposite the foot of Torrence Road. It has a frontage of 500 feet on Eastern Avenue and runs back to the Ohio River. It was raised by an average fill of about twenty-five feet to elevation 74.00.

The front is occupied by the engine house, which is 359 feet long by 71.40 feet wide, with a central projection wing 64.5 feet long by 20.4 feet wide. (Plate 79.) At the rear of the engine house and adjoining the same is the boiler house, which is 276 feet in length and sixty-three feet in width. At the rear of the boiler house a semi-circular annex, 57.5 feet in diameter connects the same with the tower around the outlet shaft. On each side of the annex and about thirty-three feet distant therefrom a brick chimney 150 feet in height and eight feet inside diameter connects with the boiler house with a 6 x 10 feet brick flue. The engine house is constructed of the best grade of sawed Bedford limestone to a height of fifty feet above the water table, and is covered with a roof of vitrified American "S" tile, supported by a steel-trussed roof frame. The interior of the walls are faced with white enameled bricks, trimmed with white enameled, hard-burned terra-cotta. Above the pilasters two single web-plate girders, thirty-four and one-half inches deep and 313½ feet long, support the tracks for a thirty-ton electric traveling crane spanning the width of the building. The projecting wing contains a vestibule entrance nineteen feet wide with a vaulted ceiling, on each side of which there is an office on the ground and second floor. The engine house contains, besides the pump pit, a toilet room and tool and storerooms on the west end, and a machine shop on the east end, with a driveway through the building between the pump pit and the machine shop. White-enameled metallic partitions enclose the several rooms and separate them from the engine room. The pump pit is 266 feet long by sixty feet wide, and twenty-two feet two inches deep, and provides room for a group of four high-service pumping engines east of the central area, and for four low-service pumping engines in the west end. A gallery six feet wide of checkered steel plates, with a railing four feet high, surrounds the pump pit at the engine-room floor level. The walls of the pump pit consist of concrete eight and one-half feet thick at the bottom and four feet at the top, and, like the foundations for the pumping engines, rest upon piles four and four and a-half feet between centers, driven to the rock. The front and end walls extend to a depth of twenty-five and the rear wall to a depth of thirty-two feet below the water table. The foundation for each group of pumps consists of concrete eight feet deep, and is 118 feet long by thirty-nine feet wide. The entire floor of the pump pit, excepting for the width of the pipe trench along the rear wall, consists of concrete on nearly a level with the pump foundations.

The boiler house adjoins the engine house, the rear wall of the latter being common to both. It is 276 feet long and sixty-three feet wide, and is supported on a concrete foundation acting as a beam between the pilasters, where a cluster of five concrete

piles resting on the bed rock, take up the weight of the building. The walls are constructed of brick, both sides being faced with Kittanning pressed brick. The walls rise twenty-eight feet above the water table, and support the steel roof and lantern frames. The roof is covered with best quality of tin-roofing plate. The floor consists of concrete eight inches in thickness.

The foundation of the semi-circular annex also rests on concrete piles, and the walls and roof are of similar construction as the boiler house. The annex contains the individual lockers for all the employees at the station, also the shower baths, washstands, water closets, and other conveniences for the men. The floor is covered with red, hard-burnt American tile. All the buildings are provided with steam heat and electric light.

A circular brick tower eighteen feet inside diameter surrounds the outlet shaft from the bottom of the connecting archway to twenty-two feet above the water table, the walls of the annex connecting with those of the tower.

The two chimneys in the rear of the boiler house are circular in shape, 150 feet high and eight feet inside diameter, and are each supported on a re-enforced concrete foundation forty feet square, eight feet below the surface. The chimneys are constructed of vitrified brick and faced with radial Kittanning pressed brick, the tops being covered with cast-iron caps. A steel ladder, both on the inside and outside reaches to the top.

A brick flue ten feet high and six feet wide, supported by twelve-inch steel I beams, connects each chimney with the boiler house.

About fifty-one feet in the rear of the boiler house two steel coal storage houses of similar construction as that at the River Pumping Station, afford a total storage for about 7,300 tons of coal. The provisions for receiving and handling coal are identical with those at the River Station, the incline and hoist house being located between the two houses.

Three of each group of engines have been erected, all being vertical, triple-expansion, crank-and-flywheel pumping engines. (Plate 80.) The low-service pumps, each of which has a daily capacity of 25,000,000 gallons, discharge into a sixty-inch diameter cast-iron main located in Eastern Avenue, and the high-service pumps, each of which has a capacity of 12,000,000 gallons per day, discharge into a forty-eight-inch cast-iron main which ascends the hill opposite the pumping station.

The sixty-inch main is located in Eastern Avenue and Third Street to its intersection with Martin Street, a distance of 11,969 feet, where the same connects with a thirty-six-inch main and a forty-six-inch main leading to the Eden Park Reservoirs, and also with two twenty-four-inch, a thirty-six-inch, and a forty-eight-inch main, all of which supply the distribution system below the hilltops direct. The forty-eight-inch cast-iron main from the high-service pumps ascends the hill opposite the pumping station to Columbia Avenue, and then follows Columbia and Humboldt Avenues to the intersection with Woodburn Avenue, a total distance of 6,063 feet. At Woodburn Avenue the main branches into two thirty-six-inch mains, one leading south to McMillan Street and thence west, while the other leads to the northeast.

A forty-eight-inch main, which was laid along Third Street, Eggleston Avenue, and Ninth Street, and extends as a forty-two-inch main along Cutter, Wade, and Faulkner Streets, and as a thirty-six-inch main along Western, McLean, and Spring Grove Avenues to Queen City Avenue, with numerous connections to existing feed mains, has very greatly increased the supply and pressure throughout the lower or business districts of the city without increasing the pressure at the pumps, which generally amounts to from seventy-two to seventy-five pounds, raising the water to elevation 248.00 to 255.00.

The laying of numerous feed mains in every direction in the hilltops or elevated territory of the city has had a like result, the pressure in many districts being increased from forty to fifty-five pounds per square inch, equal to raising the water from ninety to 125 feet, without raising the pressure at the pumps, which varies from 190 to 195 pounds, lifting the water to elevation 520.00 to 532.00.

A thirty-inch main on Queen City Avenue, from Spring Grove Avenue to the Western Hills Pumping Station (Plate 81), near Shadwell Street, re-enforces the supply and pressure in the low-service of that district, and also furnishes the supply for the pumps at this new station, which consist of two new horizontal Snow cross compound crank-and-flywheel pumping engines of 2,500,000 gallons daily capacity each (Plate 82), and of two horizontal Laidlaw & Dunn cross compound pumping engines, each of 500,000 gallons daily capacity. These pumps were taken from the old Linwood Pumping Station, overhauled, strengthened, equipped with condensers taken from the old Mt. Hope Pumping Station and serve the Westwood District, which is the highest territory supplied within the city, the ground rising to elevation 510.00.

The Snow pumps supply Price Hill and Fairmount territory and the four tanks on Price Hill, the pressure at the pumps being from 195 to 200 pounds, lifting the water to elevation 535 to 545. The tanks at Price Hill do not permit the water to rise in them

above elevation 519; therefore, in order to serve the western part of the high ground with a higher pressure and to guarantee a supply in case the present rising main should, on account of landslides, go out of service, a sixteen-inch line of pipe was laid on Queen City Avenue and on Quebec Road from Shadwell Street to Glenway Avenue, connecting at that point with the distribution system and making the tanks virtually the low point in this system.

Because of the location of the high-service pumps at the Main Station, the tanks at Mt. Auburn also practically became the low point for the high-service system east of Vine Street, and the reservoirs at Eden Park, which heretofore served as the point of supply and basis of pressure, now generally serve only as equalizing reservoirs, the main supply and pressure for all the territory below the hilltops being furnished direct by the low-service pumps, which change has increased the pressure throughout that territory, and notably so in the territory heretofore supplied by the Third Street Reservoirs, which, like all the former pumping stations, have been permanently abandoned. Instead of seven different pumping stations, there are now but two in the city, the Main Station pumping all the water which is furnished by the Water Department to consumers both in and out of the city, while a small part of it is repumped at the Western Hills Station.

Having briefly described the new Works as designed and constructed under the authority of your Board, and having explained its operation, I will follow it with a report in general form of the progress of construction under the several contracts under which the work was done — not in the order in which they were let, but as they served in completing the several parts and divisions of the work in consecutive order.

HISTORY OF THE WORK

From the very beginning of this work, considerable opposition and many difficulties were encountered. Not only was the validity of the act authorizing this improvement attacked, but after the Supreme Court of the State had passed upon and sustained the validity of the entire act, excepting Section 8, almost every important proceeding of your Board, even to the acquiring of funds, was contested by litigation, whereby much valuable time was lost in letting contracts at a period when market prices of material and labor had not yet materially advanced. Much of the same complication was encountered in obtaining the necessary real estate and rights of way. It became necessary to institute proceedings in the Probate Court of Hamilton County to acquire by condemnation the land for the River Pumping Station, settling reservoirs, filter plant, and other parts of the work near California, Ohio, and for the Main Pumping Station on Eastern Avenue. The land thus acquired near California amounted to 325.987 acres, at a cost of $91,042.50, and for the Main Pumping Station of 7.93 acres at a cost of $34,000.00. That part of the Columbia and New Richmond Turnpike, from the tollgate at Salem Pike to the schoolhouse at California was purchased from the Turnpike Company for $9,000.00. On January 27, 1899, after many efforts, a piece of land fifty feet wide between the C. & O. Ry. tracks and the Ohio River and located directly opposite the River Pumping Station, was purchased from the City of Covington for $3,500.00. This ground is required for the abutment of the bridge connecting with the intake pier. A few days after the transfer legal proceedings were instituted in Covington questioning the right of the city to sell this property. After securing by purchase the tract of land above that acquired from the City of Covington, in order to have an undisputed landing for the bridge and to control the river frontage for some distance above the intake pier, certain officials of Campbell County, Ky., interfered with the construction of the intake pier and tunnel, claiming that the bed of the river was vested in the State of Kentucky. To prevent litigation, a strip of land containing ten acres of river-bed was purchased from the State of Kentucky. Other property and the right of way for the gravity conduit and pipe lines were acquired later, as shown in the schedule in Appendix D. The amount of land acquired at California and at the Main and Western Hills Pumping Stations is shown on Sheets Nos. 1, 14, and 15.

In order that a closer and more direct control and supervision of the construction work and material might be maintained, the contracts for furnishing such were divided and separated so as to eliminate any sub-letting of parts of contracts as far as such was practicable and possible. This course very greatly increased the labor and responsibility of the Engineering Department, as it became incumbent upon it to so expedite the progress of the work and delivery of material under the several contracts that the same became co-operative without causing interference or unnecessary delay. This additional labor and obligation was fully compensated by the better enforcement of a compliance with all contract requirements, especially so far as the same relates to the various kind of pumping, electric generating, and other auxiliary machinery, sluice and gate valves, steel and cast-iron pipes and special castings, and to brass and other metallic work and structures.

THE WORK AT CALIFORNIA.

The bids for the construction of the bridge abutment, intake pier, tunnel, and pump pit were received on April 28, 1898.

They were nine in number, and ranged from $440,699.25 to $584,493.50. On May 4, 1898, the contract was awarded to F. H. Kirchner & Co., of Cincinnati, at their proposal, they being the lowest bidders.

Within two weeks work was commenced on the pump-pit site by excavating for the caisson and delivering some white oak timber and stone for the work. The construction of the caisson in the bottom of the pit was commenced on June 29th, but did not progress very rapidly on account of difficulty in obtaining the timber for both this and the intake-pier caisson. Not more than three-fourths of the pump-pit caisson was constructed by the end of the season. On October 4, 1898, and on several other dates supplementary agreements to the contract were entered into, providing for minor alterations in the construction of the caissons and pier, the principal one being to substitute granite for the limestone specified on the up-river nosing of the pier and for the pier coping and other points, and best Ohio River freestone for the body of the pier.

The pump-pit caisson was completed by the first day of May, 1899, with the shoe resting at about elevation 42.00. Work of erecting the pump-pit walls and of sinking the caisson was at once begun, also the work of constructing the intake-pier caisson. The latter was placed in its position on the river-bed in September, and the erection of the pier was commenced at once, the same being continued without interruption until October 23, when this work was suspended until the caisson rested upon the bedrock, after which the masonry work was carried up while the caisson was sunk to its proper level in the

rock with the aid of air pressure. The sluice gates and gratings were set in place as the mason work progressed, until cold weather and floating river ice in December interfered with the work.

The pump-pit caisson was sunk through about twenty feet of surface clay and through the water-bearing sand under the clay, by excavating the clay and sand in the working chambers while the masonry wall was being built, a part of the sand excavation being deposited on the deck as ballast to assist in overcoming the friction and the lifting tendency of the compressed air, which was used in the working chambers after the caisson, in August, 1899, had reached the stage of ground water. The maximum air pressure used did not exceed seventeen pounds. The caisson was sunk in this manner until the top of the deck had reached an elevation of ten feet below extreme low water, which position was reached by October 12, and brought the cutting edge of the caisson to elevation — 26.50. Back-filling of the working chambers with sand was commenced next day. The steel pump-pit shaft was sunk through about fifteen feet of sand to bedrock and then continued under air pressure until, in the following month, the tunnel level at — 72.50 was reached, at which time the pump-pit wall was also completed. The excavation in the rock was found to be practically dry, and the work of constructing the tunnel from this shaft proceeded under atmospheric pressure at a fair rate without any trouble from water until at a point 1,030 feet from the shaft quite a flow was encountered. The work on the intake pier and of sinking the intake shaft under air pressure was resumed on April 23, 1900, the work of driving and lining the tunnel from this shaft was commenced, the two headings meeting on August 17. The intake pier, as well as the bridge abutment on the Kentucky shore were completed in September. The steel shaft in the pump pit was carried up to elevation 78.75, or the engine-room floor level, and was connected at its upper end to the pump-pit wall by three horizontal steel struts and a steel plate track girder located at right angles to each other. In December, 1899, after most of the sand ballast had been removed out of the pump pit the river rose to elevation 25.20, and with it the ground water around the pump pit. Notwithstanding the solidity of the caisson deck, the pressure of the ground water was sufficient to raise the same around the central shaft and to cause a transverse crack, about one-quarter of an inch wide, in the brick work of the shaft immediately below the lower edge of the steel shell, thereby causing some leakage. This crack was closed, but on January 26, 1900, when the river rose to elevation 34.40, the shaft again cracked at this point, due to a further lifting of the caisson deck. The repair was again made, but on November 30, 1900, the river rising to elevation 42.30, the crack again opened. From careful levels, taken at various points of the deck during this period, it was found

that immediately adjoining the pump-pit wall the deck had settled 0.111 of a foot, while near the central shaft it had lifted 0.114 of a foot. Subsequent observations showed that there was no further movement of the deck near the outer wall, but that near the central shaft there was a considerable movement both ways following the rise and fall of the ground water, due to the rise and fall of the river, the deck, however, never going entirely back to the position it had held previous to any rise which was sufficient to lift the deck, it apparently taking a permanent set about five-eighths of an inch below the highest point reached by subsequent higher stages of water. The highest stage reached by the deck near the central shaft in 1901 was on April 27, after the river had reached elevation 62.40, it being then 0.413 of a foot above its original position, after which, by August 20, the deck settled 0.100 of a foot, the river having meanwhile gone down to elevation 9.00, leaving the deck 3⅝ inches high. No further attempt at closing the crack or of controlling the movement of the deck was made until late in 1903, when preparations were being made to commence the erection of the pumping machinery.

In 1898 some difficulty was had in securing from the land owners in Kentucky the land required for the intake pier and for the bridge approach to the pier, the State owning the land under the river-bed to the Ohio shore of the river. In order to avoid possible controversy with adjoining owners, it was found necessary to change the position of the intake pier upstream for a distance of about twenty-nine feet. On December 1, 1899, the contractors presented a claim of $21,500.00 for "changing the location of the caisson for the intake pier from the location set forth in the plans and specifications, and by reason of the material through which the caisson is to be sunk being different from that set forth in the plans and specifications. * * *" This claim was not allowed, because subsequent borings demonstrated that there was no material difference in the depth of water, loose material, or rock at either the proposed or the actual location of the intake pier, nearly one-half the length of the proposed location being covered by the pier as finally located. Upon further conference it was on December 15 agreed to refer the matter to a Board of three arbitrators. Your Board selected Mr. Robert Moore, of St. Louis, and the contractors selected Mr. Chas. H. Deans, of New York City, and these two selected Mr. Wm. Henry White, of New York City, as the third arbiter.

On December 30, 1899, a majority of the Board awarded the contractors $15,000.00 for extra work in the construction of the intake pier, Mr. Robert Moore not concurring.

The intake well is equipped with a six-inch cast-iron pipe, fitted at the bottom with three brass nozzles for the purpose of flushing out through a twelve-inch valve and pipe any sediment accumulating at the bottom of the well. Each well is also provided with a

ladder, the wells being covered with a floor supported on steel I beams. F. H. Kirchner & Co. completed all the work under the contract by May 1, 1901, and the final estimate was allowed on May 7, 1901, amounting to $456,631.24, which included the $15,000.00 awarded by the arbitrators.

In connection with this work a contract was, on August 9, 1898, awarded to the Vulcan Iron Works, of Chicago, for furnishing six sluice gates for openings 45 x 69 inches, one sluice gate for an opening 57 x 87 inches and for one small hand pump for the aggregate sum of $8,079.00. On November 18, 1898, a supplementary agreement was entered into with these contractors whereby they were to modify the cylinders, valves, hand pump and piping so as to adapt them for operation by air or oil instead of water at an additional cost of $956.00. These gates were all delivered in July, 1899, and the final estimate for $9,035.00 was allowed on August 12, 1899. The gates were put in place in the two wells of the intake pier by F. H. Kirchner & Co.

On May 4, 1900, seventeen bids were received for furnishing and erecting a steel Pratt truss bridge 320 feet in length to span the river from the intake pier to the abutment on the Kentucky shore, the bids varying from $19,300.00 to $23,000.00. The contract was awarded to the Brackett Bridge Company, of Cincinnati, Ohio, they being the lowest bidder. The bridge is fourteen feet wide and thirty-two feet high between center of chords, and supports a forty-pound standard-gauge track and a two-inch plank floor twelve feet wide, protected by a handrail on each side. The bridge is proportioned to sustain a live load of 600 pounds per running foot and of a concentrated load of 16,000 pounds on a truck whose wheel axles are five feet apart. The time for completion of this work was November 1, 1900, but on application your Board extended the same several times. The work was completed in December, 1901, and the final estimate, amounting to $19,300.00, was allowed on December 27, 1901.

On March 28, 1902, four bids, ranging from $12,400.00 to $19,468.00, were received for the construction of an ornate stone building over the intake pier. The contract was awarded to Isaac Graveson, of Cincinnati, he being the lowest bidder, the work to be finished by November 1, 1902. The building is nineteen feet wide and forty-three feet long, the ends being semi-circular in form. The down-stream end consists of one story twenty feet high, while the up-stream end consists of a circular tower nineteen feet in diameter and sixty-eight feet high to the top of the finial, and contains a second story twelve feet high. The walls and cornices consist of Bedford (Ind.) oolitic dimension limestone, all joints, beds, and inside faces having sawed surfaces, the outside being rock-faced. The roof over the house and tower is covered with hard-burnt American red "S" tiles. The chimney is built up of rock-faced stone and is anchored to the roof

of the tower. The ceilings of the entire first floor and of the tower room consist of metal, and the openings over the wells are covered with cast-iron plates. The track on the bridge is continued into the house. The work under this contract proceeded very slowly. The time for completing the same was extended several times by your Board on account of strikes and for other causes. All exterior work was completed in November, 1903, but the work was not accepted nor the final estimate allowed until February 12, 1904.

This house is equipped with three flat and four basket brass wire screens to cover the several ports to the intake well and shaft, with steel guides and supports for the same, and also with an electric hoist traveling on a runway supported by steel columns.

On June 22, 1906, bids were received for this work from eleven different firms, and the contract for the seven screens was awarded to the Greer Filter Company, of Philadelphia, at their bid of $1,800.00. The contract for the steel guides for the screens and for the runways and supports was awarded to the Walton Iron Company, of Cincinnati, at their bid of $3,663.00, and the contract for the electric traveling hoist was awarded to the Case Manufacturing Company, of Columbus, Ohio, at their bid of $2,200.00.

The flat screens are of two sizes, one being eight and three-quarters feet wide by ten feet high and the other two seven feet wide by ten feet high. The four basket screens are five feet wide by ten feet high and two and one-half feet deep, and are all made of steel frames covered with No. 16 B. W. G. brass wire woven to a one-quarter-inch mesh, and are raised and lowered into place by five-eighths-inch galvanized crucible cast-steel hoisting ropes. Some considerable delay was had in delivering these screens, and when received were not satisfactory, necessitating considerable amount of work on them after they were delivered to make them acceptable. The final payment was made on February 15, 1907.

The runways consist of thirty-five-pound "T" rails being bolted to the top of twelve-inch steel I beams, supported on eight-inch steel I beam columns, anchored to the wall. The guides for the various screens consist of I beams and angles properly braced and anchored to the wall, and lead from elevation 80.00 and 70.00 down to —7.00. As one of the pumps at the River Pumping Station was at times during the early fall put into service, it interfered with the placing and anchoring of the lower section of these guides. The work, however, was completed and accepted on December 21, 1906.

The electric traveling hoist has a capacity of lifting 6,000 pounds from the bottom of the well, a distance of ninety feet, at a minimum speed of ten feet per minute, traveling electrically with the load lengthwise and crosswise of the room. It is also pro-

vided with an automatic electric brake on the armature of the hoisting motor, so that should the current from any cause fail the load can be held. Some trouble was at first experienced with the hook properly fitting on the drum as it was being drawn up, but that has since been remedied. A switchboard with the necessary switches and instruments is also provided. The installing of the hoist was delayed by the runways not being erected in time. The work was finally accepted and paid for on October 23, 1907, though the same had been in use since the first of the year.

After placing the screens in service it was soon found that they required very frequent cleaning to prevent them from fouling with small leaves and fibrous vegetable matter to such an extent as to materially check the flow of the water, thereby causing an undue pressure being exerted against them. The greatest trouble was encountered during the winter months in the accumulation of fine ice, especially anchor ice, which formed rapidly when the temperature varied from 20° to 25° F. At such times the screens had to be raised and cleaned as frequently as twice an hour. Notwithstanding the close attention given them, they occasionally require repairing, and to facilitate such work, a brick building thirty-four feet long by nineteen feet eight inches wide and fifteen feet nine inches high above the bridge floor has been erected at the shore end of the bridge, with the bridge track entering the same. One side is equipped with an upright drill and forge and the other side is used as a storeroom, while a space beneath the floor is used for storing coal.

On August 7, 1908, four bids were received for the construction of this building, varying from $4,139.25 to $6,817.50. The contract was awarded to Jos. C. Stein, of Cincinnati, O., he being the lowest bidder. Work was promptly commenced, but soon interrupted by the discovery that the building encroached some twelve feet upon the right of way of the C. & O. Railway Company. As the building already rested upon the bridge abutment, application was made to the company and after a few months delay a lease was granted by it to your Board of a strip of land sufficient to go on with the erection of the building.

Work was resumed by the contractor on about October 1 and continued without any great interruption until the same was completed and accepted on December 5, 1908. The total cost of the work under the contract was $4,091.07, final payment being made on December 15, 1908.

The current for operating the motors and for lighting the buildings is brought over from the pumping station by a two conductor lead covered and armored cable anchored to the top of the intake tunnel. This cable and a six conductor lead covered tele-

phone cable was furnished and laid by A. S. Schulman, of Cincinnati, under a supplementary agreement to another contract at a cost of $2,033.50.

The screens are washed with water brought over from the pump mains at the pumping station through an 8-inch cast-iron main laid in the bottom of the tunnel. This pipe line was laid and connected up at each end by day labor, for which purpose and that of placing of the cables, the tunnel and shafts were pumped out, the settling reservoir in the meantime supplying the water required by the city.

On January 21, 1901, a contract for the extension of the pump-pit shaft was entered into with the Variety Iron Works Co., of Cleveland. The extension consisted of a steel shell 10 feet in diameter, 30 feet and 3 inches high, made of 5/8-inch steel plate and of a steel shell 6 feet in diameter above that 17 feet 6 inches long, made of 1/2-inch plate, the off-set between the two sections serving as a support for a circular turntable for a 30-ton electric traveling crane. The lower part of the 10-feet diameter section is provided with a 4 x 6½ feet entrance and the interior with landings and steps. The upper part contains the motors and hoist and the machinery of the deep well pump. The work of the shaft extension was completed on May 22, 1901, at a cost of $3,053.00.

To provide means for draining the intake tunnel and the shafts so that the same may be inspected and repaired, bids were invited for furnishing and installing a deep well pump in the pump-pit shaft, capable of pumping and raising water mixed with sand and mud at the rate of 1,000 gallons per minute 134 feet high and discharging same through a 12-inch cast-iron pipe. On May 8, 1900, but one bid was received, being that of the Pneumatic Engineering Company, offering to install such pump for $12,757.00. This bid was informal and the proposition was not a very feasible one. The work was therefore readvertised. On July 6, 1900, three bids were received, the two lowest bids being those of The Hendrick Manufacturing Co., of Carbondale, Pa., who proposed to furnish Wood's propeller pump, operated by a direct connected electric motor and included an electric generator with a steam engine of 75 horse-power, all suitably installed. Their lowest bid of $10,473.44 provided for iron tubing, while their second bid of $11,986.00 provided for brass tubing. The contract was awarded to this firm on their second bid. The pump consists of a polished steel shaft having attached thereto 52 bronze pump runner blades, the shaft being guided in babbited brass hubs held in place by 56 spring bronze guide blades, all contained in a 10-inch heavy brass tube reaching from the brass strainer at the foot of the pump-pit shaft to the discharge pipe, which tube is anchored laterally to the pump-pit shaft by 13 cast-iron frames. The shaft is supported from a pump head provided with ball bearing thrust plates supported on 12-inch channel bars and a platform in the pump-pit shaft. A platform above

supports a Northern Electric Co. vertical motor direct connected to the pump shaft. A switchboard with necessary switches and instruments is also located in the shaft handy for operation.

A Russell automatic engine direct connected to a Northern Electric Co. multi-polar generator erected on a concrete foundation in the Annex building of the River Pumping Station furnishes the current for the pump motor.

The pump and motor were installed and ready for the contract test by June 28, 1901, the steam for which was to be furnished by the city. Several ineffective attempts were made during July to test the pumps, but there being no adequate means of furnishing the necessary steam at required pressure, the test was postponed. In order to supply steam at the required pressure to make this test and to have it available in case of necessity before the permanent boiler plant at this station was erected, bids for a semi-portable steam boiler of 100 horse-power capacity, together with all necessary adjuncts and fittings were called for. On November 15, 1901, but one bid was received, being that of the New Jersey Foundry and Machine Co., of New York City, who proposed to furnish the boiler for $1,330.00. The contract was awarded to this company and the boiler was delivered complete on February 11, 1902, and paid for on February 25. This boiler was found to be of great convenience and was very serviceable during erection and other work until sometime after the permanent boiler plant of the station was installed. The boiler was finally, on October 12, 1908, sold for $105.00.

As soon as the Hendrick Mfg. Co. was ready, which was not before August 18, a test run was made. It was started at 9:05 a. m. and continued until 5:47 p. m., when the water in the sump stood three feet below the flow line of the tunnel. The actual rate of pumpage varied from 999 to 1,426 gallons per minute, with an average of 1,041.7 gallons per minute during the entire run. The speed of the pump and motor during the test was 1,100 revolutions per minute and the average speed of the engine was 301.8 revolutions. The efficiency of the automatic governor of the engine to maintain its rate of speed when the load was suddenly removed and of the ability of the machinery to start under full load were also tested and found to be quite satisfactory. The total mechanical efficiency of the installation as a whole was about 31 per cent. The test having developed satisfactory results the machinery was accepted and a final estimate rendered, 5 per cent being retained until the wiring between the generator and motor had been made permanent. This was delayed until the buildings were completed. The final payment was made on February 10, 1904, the amount of the contract aggregating $12,511.37.

On May 7, 1907, but one bid was received for furnishing and erecting an electric hoist in the pump-pit shaft, being that of the Warner Elevator Manufacturing Co., of Cincinnati, who offered to do the work for $1,350.00, and the same was awarded to them. It consisted of an electrically operated bucket hoist capable of lifting a load of 2,000 pounds at a speed of 50 feet per minute, the total lift being about 166 feet and is for the purpose of handling material safely and rapidly into or out of the intake tunnel. The motor and drum are located on a platform in the upper part of the shaft and are equipped with a rheostatic controller, an automatic electric brake, a mechanically operated load brake, a limit and a safety switch. The work was completed and paid for in November, 1907.

After the contracts for the intake pier, tunnel and pump-pit and for the pumping machinery had been let, several contracts were let for the building of culverts, the protection of the banks of the Little Miami River, the grading of the grounds, for the construction of a viaduct, and the laying of tracks for the bringing in of construction material and machinery.

On July 22, 1898, the first set of bids were received for doing work, which provided for filling the site of the River Pumping Station to an elevation about 3½ feet above extreme high water, the building of a levee or embankment 54 feet wide on top from this site to the Columbia and New Richmond Turnpike, and of two brick arch culverts under the same, the protection of the slopes with suitable revetment, the construction of a macadam roadway 16 feet wide along said levee, the grading of the grounds for the location of the filters, the excavation of the area for the clear-water basin, the re-location of a part of the Columbia and New Richmond Turnpike and for the grading and sloping of the left bank of the Little Miami River and the protection of the same. On account of an informality in the proposals of the three lowest bidders, the work was readvertised.

On August 30, 1898, eleven bids were received and compared first on a basis of protecting the river slopes with stone paving and sod and second on the basis of using rip rap and sowing in grass, the bids under the first basis running from $109,381.80 to $126,096.60, while under the second they varied from $96,733.60 to $120,341.90. On September 15, 1898, the contract was awarded to The David Folz Asphalt Paving Co., of Cincinnati, at their bid of $109,381.80. Work was at once started with a fair force, but on September 24, 1898, injunction proceedings were commenced seeking to restrain your Board from going on with the work under this contract, because the same had not been awarded to the lowest and best bidder. When the case came to trial this issue was dropped and the reason set up that the approximate amount of each class

of work had not been determined in advance of the receiving of bids, and on this ground the court held that the contract was illegal. Accordingly the contract terminated on November 19, 1898, and all work was stopped.

On March 29, 1900, the Legislature of Ohio, by Act, authorized the payment of $9,287.05 to the contractors as the balance due them under their contract and in full settlement of all claims.

All the new works near the village of California being located on the high ground to the west of Lick Run, which had no connection with any railroad line, it was quite necessary, to enable contractors to deliver their tools and supplies as well as the materials of construction and of finished machinery with the least amount of haul by teams, that a connection be established with the tracks of the Cincinnati, Georgetown & Portsmouth Railroad Co., which were located on the high grounds east of Lick Run. Such connection was of a decided advantage to the city as well as tending to reduce the cost of the works and the time necessary to complete the same. Accordingly on August 5, 1898, an agreement was entered into with the C., G. & P. Railroad Company under which your Board were to construct a viaduct over Lick Run and a track from the main line of said railroad company to the river pumping station, which said railroad company was thereafter to maintain and operate.

In accordance therewith seven bids were received on September 20, 1898, for the construction of the necessary foundations for the viaduct, which varied from $4,849.74 to $8,642.00. The lowest bid being informal the contract was awarded to the next lowest bidder, Mr. Theo. Koenig, of Cincinnati, at his bid of $5,219.00. The work consisted of building thirty masonry piers and one masonry abutment for the south end of the viaduct. On October 14, a supplementary agreement was entered into providing for clearing the site of the viaduct from trees and driftwood for $150.00 and for extending both ends of a culvert under the Columbia and New Richmond Turnpike at $4.50 per cubic yard of masonry. This work was promptly commenced, but on account of delay in furnishing acceptable stone and interruptions caused by high water this work was not completed until April 24, 1899. The final estimate for this work amounted to $4,884.67.

On September 20, 1898, seven bids were received for the superstructure of the viaduct, all of which being in some form defective and not complying with the specifications, were rejected and the work was readvertised. On November 7, 1898, fifteen proposals were received for furnishing and erecting the viaduct, the bids running from $23,850.00 to $32,724.00. The plans of the lowest bidder did not comply with the speci-

fications, the contract was therefore awarded on the next lowest bid of $24,900.00, which was the second proposition of the Ft. Pitt Bridge Works, of Canonsburg, Pa.

The viaduct consists of nine 30-feet and six 60-feet plate girder spans supported by fifteen bents resting on masonry piers of which the three at the north and the two at the south end are rocker bents, the intermediate bents are braced longitudinally in pairs, forming five towers. The viaduct is 630 feet long, all of which, except the south 96½ feet, is on an 8½ degree curve. The track consists of three 60-pound rails for a 3-feet and a 4-feet 8½-inch gauge. The structure is proportioned to carry a live load of two locomotives coupled and followed or preceded by a uniform load of 3,000 pounds per lineal foot, moving at the rate of thirty miles per hour. On May 26, 1899, a supplementary agreement was entered into providing that the 8-inch by 10-inch by 10-feet cross ties be made 12 inches thick, at an additional cost of $315.00. The erection of the viaduct was commenced on August 10 and completed on November 20, 1899, the first train passing over on November 21. The final estimate of $25,215.00 was allowed on November 24, 1899.

On October 18, 1898, three bids were received for furnishing and laying a three steel rail track on 4,200 feet of graded roadbed and 650 feet of viaduct, the rails being of 60 pounds standard pattern and all material, except the ties on the viaduct, to be furnished. The rails are laid to a 3-feet and a 4-feet 8½-inch gauge and the track is ballasted with gravel. The bids were $6,048.00, $7,560.00 and $8,610.00. The contract was awarded to Ed. W. White, he being the lowest bidder. The work under this contract was greatly impeded by the delay in completing the viaduct over Lick Run Valley. Track laying was not started until November 20, 1899. Another delay was caused by the abrupt termination of the contract with the David Folz Asphalt Paving Company, which contract included the grading of the roadbed for the track along the levee or embankment to the pumping station site. The track material delivered was, however, utilized in the construction of sidings on the filter plant grounds to facilitate the delivery of material required for the several contracts then in force. As the grading of the levee had been deferred, the contractor was relieved from that part of his contract requiring the laying of the track to the pumping station site. The contract was therefore terminated and a final estimate of $7,066.68 rendered to him on June 26, 1900.

On May 26, 1899, five bids were received for completing that part of the work left unfinished by the David Folz Asphalt Paving Co., and which covered the grading and protection of the left bank of the Little Miami River, the construction of the re-located roadbed of the Columbia and New Richmond Turnpike from Lick Run to the top of the hill, a distance of about 800 feet, and the roadbed for the railroad tracks from

the west end of the viaduct to the turnpike. The bids run from $35,476.25 to $48,791.50. The contract which required that the work should be completed by January 1, 1900, was awarded to the lowest bidder, E. C. Boyce, of Cincinnati. With proper energy the work might have been completed within the time specified, the contractor, however, notwithstanding frequent notices, failed to push the work satisfactorily. On September 13, 1899, less than one-fourth of the work having been done, he was duly served with a notice, in accordance with paragraph X of the contract, to proceed within 10 days with such force as to insure the completion of the work as specified, failing in which his rights under the contract would be terminated. On September 16 the work was abandoned by the contractor. His bondsmen, the United States Fidelity and Guaranty Company of Baltimore, thereupon applied for permission to complete the work under the contract, which request was granted on October 3, 1899. The work was pushed more energetically and the slope of the graded river bank was paved to such an elevation as to reasonably protect the same against damage by high water. On request the contract time was extended to August 1, 1900. The work was completed and accepted on August 17, 1900, and a final estimate was allowed on August 20 in the sum of $29,096.69. Of this amount $4,997.08 was paid to E. C. Boyce, the balance being paid to his bondsmen, who completed the work satisfactorily. (See Plates 1, 2 and 3.)

In June, 1899, a change in the low water channel of the Little Miami River, due to the formation of a sandbar on the right bank, directed the current almost at right angles against the left bank, where the slope was being graded and protected with rip rap and stone paving. The berm which separated the foot of this slope from the channel was to a considerable extent undermined and carried away. The current was temporarily diverted by the construction of a jetty of rip rap and by cutting a channel across the bar, but a rise of the Little Miami in July made it very evident that the safety of the revetment and of the land it was designed to protect, would be endangered unless some diversion work of a permanent character was erected to stop further encroachment of the channel.

To accomplish this it was determined to place a bank protection consisting of a row of oak piles 10 feet apart driven along the break of the bank at the toe of the slope and anchored to a second row of piles driven 10 feet in rear of the first row, the front row to be made solid by driving 4-inch white oak sheet piling between the piles, the sheet piling being held in place by 4 by 12-inch white oak guide pieces, the space behind the sheet piling being filled up level with broken rock and the space in front banked with broken rock to a 45-degree slope.

In addition to this it was proposed to build out a series of dikes consisting of two rows of piles driven 5 feet apart between centers and capped with 8 by 12-inch white oak timbers, each row of piles and the end of the dike to be closed with 4-inch sheet piling, the space between to be filled and the outside to be banked with broken rock.

On September 8, 1899, six bids were received for this work, varying from $9,444.22 to $21,300.60. The contract was awarded to Thomas Maloney, of Cincinnati, he being the lowest bidder. The work proceeded at a very slow rate, notwithstanding the contractor was constantly urged to expedite his work, as the river was constantly undermining and scouring the river bank, thereby very materially increasing the quantity of rock required to fill the scoured areas. This scouring also necessitated using longer piles and sheet piling. On January 12, 1900, the construction of the spur dikes, which formed a part of this contract, was dispensed with. The work under the contract was finally completed in June and a final estimate rendered on June 15, 1900, in the sum of $9,481.81.

In September, 1901, an additional tract of 6.85 acres adjoining the Water Works ground on the west and fronting on the Little Miami River was purchased to serve as a borrow pit for clay embankments. In the course of time the river began to cut into this ground, rapidly undermining and washing into the bank. A protection similar to the one constructed was planned and on December 4, 1903, three bids were received for this work, the bids ranging from $10,643.30 to $14,546.15. The contract was awarded to the lowest bidder, Thomas Maloney. The work was in extension of the protection completed in 1900. High stages of water and an accumulation of heavy ice in the river did not allow the work to be commenced until in March, 1904. By August all of the piling and sheet piling had been driven, but not until after further scouring made longer timber and a much larger quantity of rock necessary, the latter amount being increased over 100 per cent. A very low stage of water in the Fall of 1904 and ice in the Winter following prevented the contractor from getting rock to the work or putting it in place until after the high water in the Spring had subsided. The work was finally completed in August, 1905, and a final estimate in the sum of $19,481.49 was allowed on September 15, 1905. The protection has since answered its purpose very well, no further cutting or scouring of the bank by the current having taken place, though it has been continuously hugging this bank.

On February 6, 1900, plans and specifications were submitted and adopted for filling the site of the River Pumping Station to elevation 77, and for constructing a levee or embankment 54 feet wide on top from said site to the Columbia & New Richmond Turnpike together with a macadam roadway on said levee, for protecting

the slopes by a stone pavement and rip rap, for excavating the clear-water basin and the coagulation basins and making the embankments around the latter, for grading the filter plant grounds, for constructing and completing the diversion of the Columbia and New Richmond Turnpike across said grounds and for laying cast iron and vitrified pipe drains.

On March 20, 1900, five bids were received for doing this work, the bids running from $139,267.50 to $159,463.00. The contract was awarded to August J. Henkel, of Cincinnati, he being the lowest bidder. On May 10, 1901, this contract was, at the contractor's request, transferred to Henkel and Sullivan.

All filling and embankments were made by spreading the material in layers 4 inches in depth and by thoroughly rolling each layer, the material for the embankments being properly selected for that purpose. The revetment on the river front consisted of a pavement of stone not less than 4 inches thick and 12 inches deep, roughly squared and laid on edge in horizontal courses. All the other slopes below elevation 77 were covered with rip rap 12 inches thick, consisting of stone not less than half a cubic foot in size. The macadam consisted of two layers of broken stone on top of a layer of 4-inch thick flat stones laid by hand, the macadam being 12 inches thick in the center and 9 inches at the outer edges of the roadway.

Several supplementary agreements were added to the contract, one on July 26, 1901, for excavating about 3,100 cubic yards at 25 cents per yard of loose rock material deposited on the pumping station site by the tunnel contractors, another on August 30, 1901, for stripping the surface soil from off the land purchased to serve as a borrow pit for clay at 17 cents per cubic yard, for excavating about 30,500 cubic yards from said borrow pit which was used in the embankments of the coagulation basins at 28 cents per cubic yard, and a third agreement for taking up and relaying at another point 83 cubic yards of gutter paving at $3.00 per cubic yard. The diversion of the turnpike was completed by November 21, 1900, and the levee was nearly completed by the end of that year. All the principal work, excepting some revetment and sodding, was completed during the next season, though the work was not accepted until July 5, 1902. The time for the completion was extended several times, finally until July 1, 1902. The final estimate was allowed on August 29, 1902, and amounted to $144,860.76, of which the principal items were for 343,948 cubic yards of embankment, 2,860 cubic yards of stone pavement, 6,791 cubic yards of rip rap and 2,302 cubic yards of macadam.

The turnpike, which was acquired by your Board in 1898, crossed Lick Run on an old wooden bridge supported by weakened stone abutments. In addition to the

necessity for a new structure came the desirability to materially widen the roadway and raise it above ordinary high water. This was best accomplished by replacing the old bridge with an arch culvert 16 feet in diameter. On August 7, 1900, three bids were received for this work, which ranged from $11,264.70 to $14,135.00. The contract was awarded to F. H. Kirchner & Co., of Cincinnati, they being the lowest bidder. The structure consists of stone masonry side walls 6½ feet high, supported on a concrete foundation, which also formed the invert of the archway. The arch forms a semi-circle 16 feet in diameter, and consists, excepting the ring stones at the ends, of four rings of vitrified shale brick laid in cement mortar. The wings and head walls are constructed of stone masonry. On account of the soft condition of the soil, a layer of coarse gravel 30 inches in depth was placed under the concrete invert and foundation, which was confined by a sunken wall of concrete at each end of the invert. Under a supplementary agreement made on August 24, the contractors were permitted to erect and maintain a temporary bridge to the northwest of the work instead of over the same, the contractor making an allowance of $300.00 in consideration of this change. The work, which included filling and macadamizing the roadway, was completed on October 31, 1900, and the final estimate, amounting to $11,386.61, was allowed on November 9, 1900.

SETTLING RESERVOIRS.

On March 17, 1899, the several plans and specifications for the construction of the two settling reservoirs, the laying of two lines of pump mains thereto from the River Pumping Station and of other work in connection therewith, all of which had been previously submitted, were approved. On April 28, 1899, nine bids were received, which in the aggregate were as follows:

NAME OF BIDDER AND ADDRESS.	AGGREGATE AMOUNT OF BID.
Folz, Willard & Co., Cincinnati	$1,039,650.63
August J. Henkel, Cincinnati	1,171,743.50
Mason & Hoge Co. Frankfort, Ky	1,189,193.00
Hughes Bros. & Bangs, Syracuse, N. Y	1,198,568.60
Guy M. Gest, Cincinnati	1,210,204.75
M. Sullivan, Cincinnati	1,324,430.50
F. H. Kirchner & Co., Cincinnati	1,433,045.60
J. M. Quill, Cincinnati	1,434,798.10
Wagner Water Supply Co., Dayton, Ohio	1,499,102.50

On May 12, 1899, the contract was awarded to A. J. Henkel as the lowest and best bidder. Within ten days a suit was brought in the Superior Court by one E. C.

Coppin, who sought to invalidate the contract on the ground that the same had not been awarded to the lowest and best bidder. Folz, Willard & Co. were the lowest bidders, but in a conference had with them, it became very evident that they had based their bid on furnishing some material which had already been rejected under other contracts and that they did not fully understand the specifications nor the character of the work called for. One week after the bids were received and before the award of the contract this firm requested that they be permitted to withdraw their bid.

The suit was tried by the Superior Court in Special and in General Term and in both instances the decision was in favor of the Board. The case was finally carried to the Supreme Court of the State whose decree, on June 26, 1900, more than one year after the contract had been awarded, sustained the validity of the same. On December 13, 1899, the contractor was notified to proceed with the work. On December 19, 1899, A. J. Henkel, with the consent of your Board, sublet all of the work under this contract, excepting the asphalt, burlap and brick revetment, to R. M. Quigley & Co., of St. Louis. Work on the Settling Reservoirs was begun on January 8, 1900. During the first six months the work was confined to clearing and grubbing the site for reservoir No. 1, of building a roadway connecting the same with the Columbia and New Richmond Turnpike, and of putting up a number of buildings to serve as shops, stables, storehouses and for other purposes. No rapid progress was being made and no plan of prosecuting the work with any sort of system was being followed. In September a start was made in building the archway under the dam of Reservoir No. 1, which by the end of the year was only carried up to the spring line, notwithstanding the exceptional good weather during the fall. Not more than 9 per cent of the total amount of work was done during 1900, the major part of which consisted in handling about 220,000 cubic yards of earth, building part of the archway and shaft and of furnishing brick, stone and cement. During the winter months the two lines of 60-inch cast-iron pipe were laid in the archway. The brick arch was finished in April, 1901, and work resumed with a small force in grading and in stripping Reservoir No. 2.

The sub-contractors showed a disposition to skim over the work, ignoring the requirements of the specifications that the dam and reservoir embankments be formed of properly selected material or of a mixture of materials of different character so as to obtain a fill of homogeneous composition. The conduct of the work also showed their lack of familiarity with reservoir construction. It became evident that they were simply singling out the most profitable work wherever they could do so. On August 5, 1901, the sub-contractors formally filed a complaint with the Board that the material

encountered in excavation was of a quality and character wholly different from that represented by the plans or exhibited in samples for the information of bidders and requested that an examination and investigation be made of the test borings. On August 15, 1901, the sub-contractors stopped all work, leaving the same in bad condition (see Plates 26, 27, 28 and 29) and at the same time disposed of their horses, mules, buildings and their tool equipment. On the following day the Board ordered A. J. Henkel to proceed with the work and complete the same according to contract. On August 20 the sub-contractors filed protest to such order and a notice that they would hold the city responsible for damages. In order to determine the justice of the complaint test wells four feet square were ordered sunk alongside the test holes, which had been bored previous to the letting, in such manner as to expose one-half the test hole on some one side of the test well. On September 13 the Board appointed H. A. Carson, of Boston; Alfred Noble, of New York City, and Major W. H. Bixby, U. S. Engineer Corps, as a Commission of Engineers to examine into and report as to the facts of the contention made by the contractors that the information as furnished to the bidders was incorrect and misleading. This Commission, after an exhaustive personal investigation of each of the 14 test wells and a comparison with all the information which had been given to the bidders, reported on September 27 that the information which had been given agreed with the actual condition so far as that class of material would permit and "that the material encountered is not materially different from what a prudent bidder would have considered possible or probable."

Meanwhile the contractor offered to proceed with the work, providing the contract time would be extended for one year and he be paid 40 cents per cubic yard for all future excavation. The contract time was extended for one year or until December 31, 1903, without any increase in price for excavation. On September 10 the Board notified the contractor and his surety that unless within ten days he proceed with the work in a satisfactory manner, all of his rights under the contract would be annulled and the work completed as provided for in the contract. After a number of conferences the contractor on October 18, 1901, agreed to proceed with the work and ten days later did commence operation. Very little work, however, was done by the contractor, most of it consisting in laying sewer pipe and in unloading and storing water pipe.

Previous to this time, at the request of the sub-contractors, four supplementary agreements to the contract were entered into. The first permitted the use of vitrified brick 2¾ inches thick instead of 2½ inches as specified. The second provided for the use of Portland cement on the archway of Reservoir No. 1 instead of natural cement at an

additional cost of $1.62 per barrel. The third agreement provided for substituting Portland cement concrete of one-inch stone for the sand stone masonry specified for the open drain below the dam at a cost of $8.00 per cubic yard. The fourth, under date of April 12, 1901, provided that all waste material in excess of 4,000 cubic yards shall be paid for at the rate of 28 cents per cubic yard, which was to include extra haul. On December 3, 1901, another agreement was added whereby the contractor was allowed an additional sum of $1.00 per cubic yard for all excavation for the foundations for the archway of Reservoir No. 2, which extended below the lines originally indicated, which price was to include backfilling and ramming. Some of this excavation extended to a depth of 20 feet to remove vegetable loam.

On March 11, 1902, the contractor asked the consent of the Board to assign all his rights and interests in the contract to the United States Construction Company, of Milwaukee, Wis., said company agreeing to complete the work under the contract in accordance therewith. Consent was granted under the condition that the contractor waive any and all claims for damages against the city which have or might accrue to him out of this contract. The transfer of the contract was executed on the following day and the waiver of damages filed. On November 4, 1903, the balances due the original contractor and sub-contractor for all work done and material delivered previous to the transfer of the contract to the U. S. Construction Co. were allowed and paid, the construction material delivered being accepted by the U. S. Construction Company at the prices allowed these contractors.

The original contractor having at an early day sublet the work under Item No. 13 of the contract, consisting of the asphalt, burlap and brick revetment, to the New York and Bermudez Co., the U. S. Construction Co. also assigned with the consent of the Board said work to said New York and Bermudez Co.

Active work under the contract was commenced on April 15, 1902, but very slow progress was made (Plate 40). The lack of necessary tools and machinery, the erection of second-hand cable ways which became wrecked several times, frequent and heavy rains and finally the absconding of the President of the company impeded the work very materially. The principal work during the summer consisted in laying sewer pipes, a part of the 60-inch pump mains on the levee, and of constructing the archway under the dam of Reservoir No. 2, not any of which work was done in an economical way. Very little grading was done. One cable way across the reservoir basin was never used and the other only for a short period. Less than five per cent of the work was done during 1902 and work was entirely suspended during the winter months.

Several supplementary agreements were entered into with these contractors, one providing for the use of Portland cement instead of natural cement in the archway of Reservoir No. 2 at an additional cost of $1.67 per barrel, another providing for parting or expansion joints 3 inches deep in the concrete revetment of both reservoirs and filling same with asphalt at an additional cost of 75 cents per cubic yard of concrete revetment. In the original plan no overflow connection between the two reservoirs was provided. The failure of the reservoir at Grand Rapids, Mich., due to carelessness in permitting the reservoir to overflow and to cut away the earth dam, proved that it is not always safe to depend upon the watchfulness of attendants and that it is desirable to guard against a similar accident by providing a spillway between the two reservoirs. Such provision was covered by an agreement stipulating certain unit prices for the work which aggregated to about $3,147.25. On April 10, 1903, on the representation of the contractors that there was a greater amount of conglomerate than was expected (see Plate 30) and that the material as actually found in the necessary excavations of the reservoirs, is in many places of a more variable character than was expected, making a proper selection and admixture of same for reservoir embankments much more expensive, a supplementary agreement was entered into allowing the contractors an additional sum of 7 cents per cubic yard for all material thereafter placed in reservoir embankments in further consideration of which the contractors are to waive all claims for damages which have arisen or may thereafter rise in connection with this part of the work.

Work was resumed with a small force of men in March, but was not pushed with any energy during any time of the year. Only about 85,000 cubic yards of earth were moved, half of it being placed in the dam and the other half in shaping Reservoir No. 1 (Plate 41). The sewer pipe around this reservoir and about 5,200 feet or one-half of the 60-inch pump mains were laid. The total work done during the two years amounted to less than $130,000.00, of which $80,658.70 worth was done during 1903. Work was again shut down on December 3, 1903, notwithstanding frequent orders to proceed with greater energy. Upon repeated notices the company in March proceeded to protect the work against erosion by heavy rains, but did nothing more. On April 1, 1904, the Board served notice on the contractors and their sureties that if they did not within ten days proceed with the work in a proper manner the Board would terminate their rights in the contract and proceed to relet the work, holding them liable for all damages sustained by virtue of their failure to perform the contract. The contractors temporarily enjoined the Board from proceeding under this notice until June 18, 1904, when the injunction was dissolved. On June 24, the Board by

resolution cancelled all rights of the U. S. Construction Co. in Contract No. 12, and on July 15, 1904, directed that plans and specifications be prepared for completing the construction of the Settling Reservoirs, the laying of pump mains and other miscellaneous work in connection therewith, the same to include all provisions covered by supplementary agreements. As there was some doubt whether the work of lining the reservoirs with asphalt, burlap and brick under Item No. 13 could be relet, it having been assigned to the New York & Bermudez Co., it was decided to receive bids separately for Item No. 13, and for all the work excepting Item No. 13.

On September 9, 1904, six bids were received, one covering all the items required to complete the work, three covering all the items except No. 13, and two covering Item 13 only. On that same day the Board was enjoined by the New York and Bermudez Co. from receiving any bids for the work embraced under item No. 13. The bid, which covered all the items, being in every respect identical with another bid submitted by the same party, excepting that it included a bid for item 13, the same was disregarded. The three bids received which did not include Item 13 were as follows:

NAME OF BIDDER AND ADDRESS.	AGGREGATE AMOUNT.
Keeling & Ridge Co., Pittsburg, Pa	$719,821.25
F. H. Kirchner, Cincinnati, O	911,464.90
The Western Construction Co., LaFayette, Ind	1,148,089.60

On September 27, 1904, the contract was awarded to the lowest bidders at the prices named in their proposal, which prices increased the cost of completing the work $50,770.64 above what it would have cost at the prices of the former contract and supplementary agreements.

In June, 1905, the Circuit Court of Hamilton County set aside the injunction of the New York and Bermudez Co., on the ground that said Company had no contract with the Board for Item 13, nor any rights under the assignment from the U. S. Construction Company, to which assignment the Board had simply consented. The bids received on September 9, 1904, for the work under Item No. 13 were on July 7, 1905, taken up and found to be as follows:

NAME OF BIDDER AND ADDRESS.	AGGREGATE AMOUNT.
J. S. Jackson, San Francisco, Cal	$298,517.60
F. H. Kirchner, Cincinnati, O	344,258.20
Keeling & Ridge Co., Pittsburg, Pa	385,184.00

On July 14, 1905, the contract was awarded to the lowest bidder at his proposal, which, in the aggregate, was $62,592.40 below the price for said work under the former contract. The entire work of completing the settling reservoirs, laying the pump

mains, and other work, was, therefore, relet at an amount aggregating $3,821.76 below what the work would have cost if completed under the former contract.

On the following day the contractor, with the consent of the Board assigned and transferred said contract to the Kirchner Construction Co. of Cincinnati.

The Keeling & Ridge Company commenced work under their contract on October 19, 1904. Some considerable delay was occasioned by the receiver for the U. S. Construction Co. failing to promptly remove from the work the tools and machinery belonging to said Company. The contractors with a small force continued work during the winter months, increasing the amount of work with the return of the working season, yet not to any such extent as an energetic contractor experienced in this class of work could have performed. Moreover, these contractors caused constant trouble on this as well as other contracts by their willful and sometimes utter disregard of contract obligations. Only about 24 per cent of the amount of the contract was done by the end of 1905, consisting principally of building 118,000 cubic yards of embankment, of wasting 54,000 cubic yards of excavation, of placing 5,200 cubic yards of broken stone and 6,500 cubic yards of concrete in revetment, of laying 3,700 feet of 60-inch pump mains, and of furnishing considerable construction material. Under the terms of the contract reservoir No. 1 was to have been completed by December 1, 1905, and the entire work by October 1, 1906. On November 28, 1905, the contractors applied for an extension of time to October 1, 1906, within which to complete reservoir No. 1. On December 8, the time was so extended upon the express condition that the contractors shall from and after the month of March, 1906, perform work under said contract at a rate representing not less than $30,000.00 each month. During the winter months the principal work consisted of wasting conglomerate and gravel, much of which might have been used for the broken stone revetment. Early in spring a reorganization of the force took place, and the same was entirely concentrated on the work of reservoir No. 1. Much greater energy was displayed, and better progress made, with the result, that with the contractor for lining the reservoirs closely crowding the Keeling & Ridge Co., the basin of reservoir No. 1 was completed by November 15, 1906. The same was thoroughly cleaned and water was pumped into it for the first time on the afternoon of December 10, up to elevation 96, at which stage it was left during the winter months. On March 2, the reservoir was drained to examine and test all the drain pipes and valves, in which some refuse was found and removed. On March 6 pumping into the reservoir was resumed, and on the day following it was put into regular service, and has since continued so, excepting for a short period in the Fall

of 1907, when it was drained sufficiently to allow the second floating tube to be put in place. The closest examination and tests have not revealed that there is any leakage whatever out of this reservoir.

In September the contractor transferred his steam shovels into reservoir No. 2, and continued doing some small amount of work until early in December, when grading was stopped for the Winter.

There having been but one outlet provided at the lower end of each reservoir, through which to drain and flush out the sediment, it was deemed best to provide three additional outlets in each reservoir, equally distributed as to area, so as to facilitate and quicken the process of draining and cleaning the same. For that purpose, a supplementary agreement was entered into with the contractors to lay a drain consisting of 24, 20 and 16-inch cast iron pipes under the bottom of each reservoir, with three special drain inlets covered with hoods, and to lay a 10-inch instead of an 8-inch cast iron flush pipe around each reservoir at prices stipulated therein. On January 30, 1906, another agreement was entered into, to substitute Portland cement concrete for all the stone work specified for the cascades and stairways of the two reservoirs, at $9.00 per cubic yard. On September 28, 1906, the contractors again applied for an extension of the contract time to October 1, 1907. The consideration of this application was postponed until the work in reservoir No. 1 was practically completed, when on January 8, 1907, the contract time for completing all work was extended to September 1, 1907, with the provision, that they prosecute the work after April 1 with a force sufficient to do not less than $50,000.00 worth of work during each month thereafter until the same had been completed.

Practically no work of any kind was done during the winter months until March 25, 1907, when one steam shovel was set at work in the borrow pit.

On April 5, 1907, the Board was notified that the Keeling & Ridge Co. had assigned all its rights and interests in this and other contracts to the Mercantile Trust Company of Pittsburgh, who had undertaken to complete the work under the several contracts. This action was finally approved of by the Board on April 23. The Trust Company immediately placed the work under the management of J. S. Jackson, who had charge of lining the reservoir under another contract. From this time on, as soon as an ample equipment and force of teams and labor could be secured, the work progressed with an energy heretofore unknown on the reservoir work. In the fall an extension of time was asked for and same was granted to October 1, 1908.

On the east slope of the north arm of reservoir No. 2 a slide had manifested itself, and work at that end was suspended in 1906. During the early spring of 1907

the movement of the slope, which constituted the lower section of a very considerable hill side, increased to an extent so as to amount to from five to thirty feet in width, for over four hundred feet in length along the upper edge of the basin. An examination of the sub-strata by means of test holes developed the fact that the surface of the stratified rock takes a sudden dip to the west immediately below the lower edge of the area that had moved. As it would be quite difficult to solidify this disturbed area so as to prevent further slipping, or to make it suitable for a reservoir embankment, it was decided to exclude this section from the basin area, and change the contour lines of the reservoir to that end, and by excavating a large part of the adjoining point which projected into the basin, and by flattening these slopes from 3 to 1 to 6 to 1. This modification reduced the available capacity of the reservoir about fourteen and a half million gallons. It also materially increased the amount of excavation and embankment, while at the same time it considerably decreased the slope area of this part of the reservoir, thereby reducing the amount of clay, broken stone, concrete, asphalt and brick revetment. Plans showing the changes were submitted to and approved by the Board on November 22, 1907. As this change, to some extent, increased the cost of the work, the contractors by a supplementary agreement were allowed an increase of fifty cents per cubic yard for such additional conglomerate as the contractor would encounter in the point because of this change, and thirty cents additional for each cubic yard which the change in this point necessitated to be hauled "up hill."

At the request of the contractor permission was given to substitute Portland cement concrete at $10.50 per cubic yard for the stone curb around reservoir No. 2, as far as the stone on hand was insufficient to complete the same.

On December 15, 1907, all grading work was stopped and remained suspended until March 23, 1908, when operations were resumed with a fair force and pushed with considerable energy. Wet weather interfered very much with the progress during the first month, allowing the work to proceed only about half the time. This, however, was made up later by the unusual long period of fine weather, which enabled the contractors to push the work without interruption, and at times with a force of nearly four hundred men and over 120 teams. This exceptional weather lasted until December, and practically through that month.

The work in the reservoir basin was finished by October 4. Considerable work in laying drains and water pipe, of macadamizing the roadway, cleaning and trimming the grounds and seeding or sodding the same remained to be done. All of this work, except some grading, trimming of grounds and of seeding and sodding was done by the end of the year. On account of the extraordinary dry weather during the

entire Summer and Fall no good sod was to be had, and as the contractor was anxious to do this work, the time for completing this work was extended to May 1, 1909.

The total amount of work done under this contract up to January 1, 1909, amounts to $786,970.66. The amount of work which remains to be done will not exceed $15,000.00.

The contractors for lining the reservoirs with asphalt, burlap and brick closely followed the concrete lining, and their progress was such that they were obliged to suspend work a number of times for periods of two to three months during the working season, or until a sufficient amount of the reservoir surface had been covered with concrete to warrant re-assembling a force to proceed with their work.

On December 8, 1905, a supplementary agreement was entered into with the contractors permitting them to lay the brick on top of the asphalt, herring-bone fashion, with joints at right angles to the line of the curb, instead of at an angle of 45 degrees and without previously warming the brick, in consideration of which modification the contractors provided a half-inch expansion joint every 75 feet in the brick lining along the three to one slope of the reservoirs, said joints being filled with rubber asphalt to a depth of 2½ inches.

As has been stated, the contractors followed the concrete revetment of reservoir No. 1 very closely and completed their work in connection with it on November 15, 1906.

No further work under this contract was done until October 3, 1907, when some of the joints in the concrete lining of the upper part of reservoir No. 2 were cleaned out and filled with asphalt, preparatory to covering the concrete with the layers of asphalt, burlap and brick which was commenced on October 16, and continued until cold weather, at the end of December, interfered. On March 16, 1908, this work was resumed and continued until June 29, when work was again suspended for want of finished concrete revetment.

A fair amount of the slope having been lined with concrete, the work of laying the asphalt and brick was resumed on August 6, and continued until the entire work was completed, on October 17.

Water was first let into reservoir No. 2 on October 21, 1908, although the floating tubes had not been lowered or put in place. This became necessary on account of the extreme low stage of the river, which made it necessary to store as large a supply as possible.

The reservoir was filled to elevation 129.00, when it was noticed that the stage of the river was slightly rising, and as it was desirable to place the floating tubes in position, the water was gradually drawn out of the reservoir and sent to the coagulation basins. On November 5, while the water was being drawn off, a rise and break

was noticed in the reservoir lining on the 6 to 1 slope at elevation 114.00, and at a place where the point projecting into the basin near the northeast end of the reservoir had been removed by excavation. On examination it was found that the break was caused by water accumulating underneath the concrete lining which, as the water in the reservoir was drawn down, released itself in this manner. Later similar lifting and breaking of the lining was observed to have taken place at several other points, including the bottom. As there had been no indications of any water during the entire summer and fall at any of the places where these breaks occurred, and as there was no evidence of any water after the reservoir and these places had been drained, it was quite evident that the water accumulated by leakage through the brick, asphalt and concrete lining while the reservoir was partially filled. A test of the drain pipes below the reservoir bottom showed that these were not tight, but that under a very slight head the leakage amounted to about 20 gallons per hour. This leakage may have been the source from which the water accumulated under the lining of the bottom of the reservoir. No evidence of any leakage through any of the reservoir embankments was discovered. It was found to be impossible to locate the leakage in the pipe without uncovering the same, and as that was not advisable, the inlets to the drain pipes were capped and the outlet valve opened, so that there could be no accumulation of water in or a leakage of water out of these drain pipes. At no places where the lining had been lifted and broken was there any indication of slipping or sliding of any part of the same. The reservoir was entirely drained, the sections of the broken revetment taken up and relaid. At these and various other points in the lining, at about elevation 110.00, two and one-half inch brass pipes, with special ground check valves were inserted to release any water which might again gather underneath the asphalt or concrete lining and thereby prevent the same from accumulating under such a head as to again lift and break the revetment. Water was again let into this reservoir on the afternoon of December 31, 1908. As but two pumping engines at the River Station were in service, the other two being painted, the filling proceeded slowly. The reservoir was filled to elevation 140.10 by January 18, and allowed to stand for a number of days, during which time close examinations were made for leakage. The only leakage found was along the outer side of the 30-inch drain pipe into the archway and at two points in the archway, the total maximum leakage amounting to a little over a gallon per minute. On January 24 the water was again slowly drawn out of the reservoir, down to elevation 109.10 for the purpose of noting the behavior of the reservoir lining, and what, if any, flow there would be from the twelve drain pipes. All of these except one showed a free flow of water into the reservoir from the under side of the concrete

lining, the rate of discharge varying from 3¼ to 10½ gallons per minute. No movement of the lining was observed, undoubtedly due to the relief afforded by the drain pipes, although some leakage was noticed coming through two or three places in the brickwork. These conditions clearly show that the work of lining reservoir No. 2 was not as thorough as in No. 1. It would be next to impossible to locate the particular defective work covered by a layer of brick over so large an area. The defective work is not of such a character as to prohibit the use of the reservoir, but greater care will have to be exercised in draining the same down to the lower levels. It may be possible that the fine clay particles which will settle out of the water will in time reduce or even close up the leaks which in no case are of any perceptible size. The reservoir is again filled, and is in regular service.

An adjustment was finally arrived at by deducting the sum of $1,816.17 from the final estimate, and final payment was made on March 19, 1909. The total cost of this work under this contract was $277,189.60.

The total cost of constructing the reservoirs under the original contract, and the several contracts which followed out of it, is as follows:

A. J. Henkel—Contract No. 12	$177,791.11
U. S. Construction Co.—Assignee	111,962.94
Keeling & Ridge Co.—Contract No. 49	312,179.70
Mercantile Trust Co.—Assignee—up to January 1, 1909	396,746.04
Kirchner Construction Co.—Contract No. 57	277,189.60
Total cost to date	$1,275,869.39

Under a contract with the Riter-Conley Mfg. Co. for steel pipe and with the Norwood Engineering Co. for operating machinery, hereafter referred to, four steel floating tubes and floats and four sets of cast iron swinging elbows were furnished for the settling reservoirs. The four sets of elbows connect with the upper end of each of the two 60-inch effluent mains at the upper end of the pier leading to the archway under each dam, and are so arranged as to swing with the position of each of the floating tubes as the water in each reservoir rises or falls, the floats holding the strainer at the outer end of the tube constantly about two feet below the water surface. By means of ⅝-inch special chains attached to the tubes and wheels, and a crab back of the reservoir curb, the tubes can be brought to any position desired when the floats fail to act.

The floating tubes and floats were delivered by June 1, 1906, and were paid for in September, the cost being $4,882.00.

The swinging elbows were delivered in March, 1907, but were not finally paid for until one year later because one of the elbows had to be replaced, it having proved to

be a defective casting. The cost of these elbows and four smaller auxiliary floats was $9,008.00. The floating tubes and the elbows were placed in position and connected up by day labor when said work would not interfere with supplying the city. The west tube in reservoir No. 1 was installed in February, and the east tube in December, 1907. The tubes in reservoir No. 2 were installed early in December, 1908.

On May 9, 1899, plans, specifications and form of contract for the cast iron pipes and special castings for the settling reservoirs and for the pump mains from the River Pumping Station were adopted and ordered advertised. On June 13, two bids were received, one from the U. S. Cast Iron Pipe & Foundry Co., proposing to furnish the pipe for $27.50 and $30.50 per ton, the other being from the Camden Iron Works, whose bid was $26.00 and $33.00 per ton.

Both bids being considered excessive, no award was made. Similar action was taken on the only bid received on July 3 from the U. S. Cast Iron Pipe & Foundry Co. for furnishing special castings for the settling reservoirs, the intake, the pump pit, and valve chambers.

Work on the settling reservoirs having commenced on January 8, 1900, it became necessary to no longer delay the securing of pipes and special castings required for draining the reservoirs, and for the effluent piping. Such pipes and castings as would be needed during the year were, therefore, advertised for, and on February 3, 1900, three bids were received, two of which were informal as not complying with the specifications. The third bid, which was $1,495.20 above the lowest bidder, was that of the U. S. Cast Iron Pipe & Foundry Co. and was $29.50 per ton for hub and spigot pipe, $60.00 per ton for flange pipe and $70.00 and $80.00 per ton for special castings and $1.00 per ton for cleaning pipe and specials by sand-blast, aggregating in the sum of $37,737.00.

The contract was on February 27 awarded to this Company, and provided for furnishing 955 tons of pipes and 105 tons of special castings, the greater part of which were 60 inches in diameter. All the material was delivered before the end of the year, but final payment was not made until May 7, 1901, because of differences existing in the statement of weights. The total amount of work done under this contract amounted to $33,648.50.

On November 13, 1900, two bids were received for furnishing cast iron pipes and special castings for the settling reservoirs and the pump mains from the River Pumping Station. The U. S. Cast Iron Pipe & Foundry Co. were the lowest bidders, who proposed to furnish the hub and spigot pipe at $24.50 per ton, flange pipe at $60.00, and special castings at $70.00 and $80.00 per ton, and to clean all pipes and specials by

sand blasting at $1.00 per ton, the aggregate amount being $175,370.00. The contract which calls for 5,263 tons of straight pipe, over 90 per cent of which were 60 and 72 inches in diameter, and 511 tons of special castings, was on November 16 awarded to the U. S. Cast Iron Pipe and Foundry Company.

The progress on this work was very slow, as the contractors were not properly equipped at their new plant at Addyston to clean the pipes and specials by sand-blasting, nor to coat them in the manner specified. More than six months were lost in compelling the contractors to comply with these requirements, and to provide proper equipment for dipping all pipe vertically, after which no further trouble was had on this account, though the delivery of pipe, and especially of special castings was very dilatory. The delays of the contractors in constructing the reservoirs and of laying the pump mains obviated the necessity of crowding the delivery of the pipe and the time for completing the contract was extended a number of times. The contract was completed in April, 1903, and the final estimate in the amount of $179,568.98 was allowed on May 8, 1903.

On December 14, 1900, plans, specifications and form of contract for furnishing the gate valves, sluice valves and mud valves required for the settling reservoirs and for the pump mains from the River Pumping Station were approved and the work advertised. On January 22, 1901, six bids were received, varying from $28,445.00 to $94,756.50, the latter being evidently a clerical error, it having been intended that the aggregate bid be $29,044.30. The plans which accompanied all the bids were, with but one exception, found to be incomplete. On January 30 all bids were rejected and the work re-advertised. On March 5 three bids were received which were as follows:

NAME OF BIDDER AND ADDRESS.	AGGREGATE AMOUNT.
Eddy Valve Company, Waterford, N. Y.	$36,700.00
Coffin Valve Company, Boston, Mass.	37,711.00
Ludlow Valve Mfg. Co., Troy, N. Y.	38,046.00

The plans and specifications, which accompanied the proposal of the second lowest bidder, being most satisfactory, the contract was on March 8 awarded to the Coffin Valve Company of Boston. This contract covered two 72-inch sluice valves and nineteen 60-inch gate valves, besides a number of smaller gate valves, and provided that the 60 and 72-inch valves be equipped, in addition to hand operating gears, with electric motors and motor stands, switchboards and switches with all suitable wire connections, suitable to open and close the valves by electric power. The construction and test of these valves, as well as of the motors, was subject to constant inspection. A large amount of the work was done by December, 1901, and all of it was complete,

ready for delivery by May, 1902, but as the work of laying the 60-inch pump mains was making very slow progress, an agreement was entered into with the Coffin Valve Company by which in consideration of $35.00 per valve, they were to store and protect all the 60-inch gate valves under cover until such time as they should be needed. Under this arrangement these valves were stored in Boston until the end of 1902. Under another agreement the contractor furnished ball-bearings under the collars of the operating stems of the 72-inch sluice valves at a cost of $30.00 for each valve and also furnished brass bearings for the guides of the mud valves at $20.00 per valve and two extra sets of motor stands for 60-inch valves with extra underground shafts, pipes and gearings at a cost of $400.00.

A final estimate for all the work was allowed on March 12, 1903, in the sum of $40,235.50.

RIVER PUMPING STATION.

After the contract for the pumping machinery for the River Station had been awarded and it became known what height of engine room as well as what space would be required for the boiler plant, plans and specifications were prepared for the engine house, boiler house and an annex, and on June 24, 1902, six bids were received for the erection of these buildings, together with the necessary foundations for the annex, the boiler house, and a steel coal storage house to be erected later on, and for necessary drains and other work in connection therewith. These bids varied from $183,230.75 to $218,781.42. On July 11, 1902, the contract was awarded to the United States Construction Co. of Milwaukee, Wis., they being the lowest bidder.

On July 8 three bids were received for the construction of the chimney for this station, which bids varied from $14,950.00 to $16,300.00. The contract was awarded to the United States Construction Co., who were the lowest bidder. The work on both of these contracts proceeded rather slowly from the very start. Some trouble was experienced because of the class of workmanship which was employed, also on account of the Company being unable towards the latter end to meet its obligations, which resulted in the Company, on March 18, 1904, consenting to the creditors assuming the completion of the contract for the buildings and to the appointment of a Trustee, who, in behalf of all creditors thereafter, received and disbursed all moneys due under the contract. The time for the completion of both contracts was extended a number of times, the one for the buildings being finally extended to July 1, 1904. The chimney was completed on November 4, 1903. On November 13, 1903, a supplementary agreement was entered into whereby the contractors were to furnish and use elastic roofing cement in laying the tile roof covering for all the buildings at an additional cost of

$1,000.00. Although some of the work was not in a satisfactory condition, the same was finally accepted on July 29, 1904, so as to permit the contractors for the boilers and other parts of the machinery to proceed unhindered with the erection of the same. A deduction of $715.00 was made from the final estimate for the replacement of defective work. The final estimate for the chimney was $14,950.00 and that for the buildings amounted to $190,068.74, which included $1,106.97 allowed on extra bills, but did not include material furnished by the Board from another contract to the amount of $1,068.94.

On January 19, 1904, five bids were received for furnishing and installing a steam heating system in the buildings at this station, consisting of radiators and coils properly distributed and connected up with the steam main. These bids varied from $2,380.00 to $5,300.00. The contract was awarded to T. J. Nichol & Co., of Cincinnati, they being the lowest bidder. The work was commenced on March 18, and completed on May 12, 1904. Ten per cent of the contract price was retained until, according to the contract provision, a test could be made of its heating capacity during cold weather. This test was made during severe cold weather in February, 1905, and was found to be entirely satisfactory. The final payment was thereupon made. The total cost of the work was $2,380.00.

Early in 1903 plans and specifications were prepared for the superstructure of steel coal storage houses for the River and the Main Pumping Stations, the foundations having been built under other contracts. The house at the River Station has a capacity of storing 7,280 tons and the two houses at Main Station have a capacity of 7,580 tons. The work included trestle approaches, inclines and tracks necessary for transferring the coal from barges in the river to the storage houses. On March 17, 1903, five bids were received which varied from $89,000.00 to $142,657.00 for the house at the River Station, and from $104,600.00 to $162,851.00 for the houses at the Main Station. The contract for the whole work was awarded to Chas. L. Strobel, of Chicago, he being the lowest bidder. During the progress of the work several changes were made which were covered by supplementary agreements. One was to substitute 6-inch matched sheathing boards planed on one side for the 8-inch plain boards specified for the roof, at an additional cost of $258.00. The other provided for substituting steel trestle bents for the wood bents supporting the track and hoisting house platform between the two houses at the Main Pumping Station, and for furnishing and erecting a steel stairway with wooden treads and railing to this platform, and for furnishing additional concrete blocks for the foundations piers at an additional cost of $2,925.00.

As quite a settlement of the 226 foundation piers for the coal storage houses at the Main Station had taken place, of which special mention is made later on in this report, it became necessary to bring them up to a uniform elevation, and also to make provision for future adjustment of the elevation of the column bases in case of further unequal settlement. This was covered by a supplementary agreement and provided for a considerable change in the anchor rods and the sole and brass plates, and for furnishing extra pipe sleeves, screw studs and special washers, at an additional cost of $2,620.00. The work under this contract, with the exception of that covered by substituting steel for wood trestles, was practically completed within the time specified in the contract and with a minimum amount of friction. The cost of the house at the River Station was $89,129.00, and of those at the Main Station $110,274.00.

On February 23, 1906, bids were received for constructing and erecting at each of the two coal storage houses a coal hoisting engine with appurtenances and two movable steel aprons and six two-ton steel coal dump cars. But one bid was received for the machinery and aprons, being that of the I. & E. Greenwald Company, of Cincinnati, and two bids were received for furnishing the twelve cars. These were $1,656.00 and $1,800.00, respectively, and as the above Company also was the lowest bidder for the cars the contract for the entire work was awarded to them at their bids, which aggregated in the sum of $13,309.00. The hoisting engines were erected in a house provided for that purpose at the upper level of the several inclines.

The steel aprons were provided to span the distance between the tracks on the incline and the tracks on the unloading barge at any stage of the river water above elevation 16.00. During the delivery of coal at each station later on it was found that the distance between the center of tracks on the inclines did not always agree with the spacing of the tracks under the coal hoppers of the unloading barge and some changes had to be made on the steel aprons to permit of their adjustment to the tracks on the barge. It may in time be found desirable for the city to provide its own unloading barge on which the tracks and hoppers will correspond with those of the incline tracks.

All of the material and machinery was delivered and erected during the month of June, 1906, and its operation tested later on.

During one of these tests at the River Station, made in the presence of Mr. S. Vivian, the Mechanical Engineer and Draughtsman of this Department and who had charge of the work under this contract, an accident occured which resulted in the death of Mr. Vivian a few hours later. The accident was caused by a loaded car, which had reached the top of the incline, suddenly leaving the track near the hoist-

ing drum and pinning Mr. Vivian, who was but a few feet away, against the side of the hoist house. In the death of Mr. Vivian this Department lost one of its best men and an exceptionally careful, reliable and competent engineer and a modest and industrious co-worker.

The tests showed that all contract requirements had been complied with and the work was accepted. The last payment was made on April 5, 1907.

As heretofore mentioned the first contract for any part of the new works was awarded on December 23, 1897, to the Lane & Bodley Co., of Cincinnati, and covered the furnishing and erection of four vertical triple expansion pumping engines, each of thirty million gallons daily capacity with the necessary boiler equipment and a thirty ton electric traveling crane for the River Pumping Station. The contract provided that within three months after the award of the contract complete and accurate detail working plans and specifications of all parts of the machinery, denoting clearly the dimensions, the different kinds of material and the character of workmanship to be employed, must be submitted to the Chief Engineer for his approval. On March 22, 1898, the contractors applied for an extension of 45 days within which to submit such plans, which extension was granted. Very little satisfactory progress was made. The contractors submitted a number of studies which were not generally satisfactory, especially after they had taken away the work of preparing these plans from the party who had designed those which accompanied the proposal. A constant effort to pare down the weights of the pumping machinery and frames was quite apparent. No plans entirely acceptable were ever submitted.

On January 5, 1899, a suit was brought in the Common Pleas Court by a citizen to test the validity of the contract with the Lane & Bodley Co. on the absurd grounds that complete detail plans and specifications had not been previously prepared; in other words, that the pumping machinery, boilers, and auxiliary machinery had not been fully designed in detail before proposals were invited, a practice which had so far secured for the engines at the Front Street Pumping Station, the reputation of being an unusual lot of remarkably antiquated machinery. The specifications upon which bids were invited were in the usual form, setting forth the general conditions and the requirements which were to be met, and invited the leading and best experienced designers and pumping engine builders of the country to compete. The case was tried in the local courts and was finally, on May 16, 1899, passed upon by the Supreme Court of Ohio, each court deciding in turn that the Board had taken proper action to serve the best interests of the city and fully sustained the same.

During this time the contractors made no progress except to furnish the foundation bolts and washers for the four engines, which were built into the pump pit caisson deck. Some castings for several machine tools specially designed for use in constructing these pumping engines were made, but nothing more. On September 12, 1899, some fourteen sheets of incomplete detail drawings for the engine frames, pumps, shafts and fly wheels were finally submitted for approval. A few additional sheets of detail plans were submitted before the end of the year, but no work was done at the shops, nor material offered for inspection, notwithstanding repeated and urgent requests were made to proceed with greater diligence in accordance with the contract.

On December 26, 1899, the Board notified the contractors and their sureties that unless they would within twenty days submit complete and accurate detail working plans and specifications for all parts of the machinery as provided for in the contract, denoting clearly the dimensions, the different kinds of material and the character of workmanship to be employed in each and every part thereof, the Board would proceed to cancel and terminate all the rights of the contractors in said contract and proceed to relet the same, holding them and their sureties responsible for any loss or damage that might accrue to the City as a result of their failure to complete said contract.

On January 12, 1900, the Lane & Bodley Co., in reply to said notice sent in a lengthy protest against the proposed action of the Board, concluding with the statement that they rescinded the contract. Thereupon, the Board requested the corporation counsel and the Legal Clerk to prepare the necessary resolution to cancel the rights of the contractors in said contract, and to order new specifications to be prepared, whereupon to relet the unfinished part of the work.

Such resolutions were submitted and adopted on January 16, 1900. On January 19, forms of advertisement, proposal, specifications and of contract were submitted to the Corporation Counsel and Legal Clerk, approved by them and adopted by the Board. The work was advertised, bids to be opened on March 9. On February 2, the time for opening bids was extended to April 17, 1900. On that day seven proposals were received from four bidders, which were as follows:

NAME OF BOILER AND ADDRESS.	FOUR PUMPING ENGINES & BOILERS	ELECTRIC CRANE	AGGREGATE AMOUNT
The Camden Iron Works, Camden, N. J.....	A— $826,000.00	$12,000.00	838,000.00
	B1— 885,000.00	12,000.00	897,000.00
	B2— 865,000.00	12,000.00	877,000.00
The Frisbie Engine & Machine Co., Cincinnati, Ohio.....	837,954.00	15,000.00	852,954.00

NAME OF BIDDER AND ADDRESS.	FOUR PUMPING ENGINES & BOILERS	ELECTRIC CRANE	AGGREGATE AMOUNT
Holly Mfg. Co., Lockport, N. Y.	A—$1,195,000.00	$6,000.00	$1,201,000.00
	B— 1,057,000.00	6,000.00	1,063,000.00
E. P. Allis Co., Milwaukee, Wis.	1,287,500.00	12,500.00	1,300,000.00

The plans and specifications of the two lowest bidders were not free of objectionable features, and the bids of the other two firms being considered too high, the Board, on May 6, 1900, rejected all bids. On August 10, the work was readvertised, and on October 16 seven bids were again received, which were as follows:

NAME OF BIDDER AND ADDRESS.	FOUR PUMPING ENGINES & BOILERS	ELECTRIC CRANE	AGGREGATE AMOUNT
The Kilby Mfg. Co., Cleveland, O.	1— $815,757.00	$7,500.00	$823,257.00
	2— 815,757.00	10,000.00	825,757.00
	3— 819,350.00	7,500.00	826,850.00
	4— 819,350.00	10,000.00	829,350.00
Camden Iron Works, Camden, N. J.	841,000.00	9,750.00	850,750.00
Holly Mfg. Co., Lockport, N. Y.	987,700.00	10,000.00	997,700.00
The E. P. Allis Co., Milwaukee, Wis.	1,044,000.00	11,000.00	1,055,000.00

On November 13, 1900, the Board rejected all the bids as unsatisfactory, and directed that new proposals be invited, bids to be opened on December 18, 1900. On that day eleven proposals were received, which were as follows:

NAME OF BIDDER AND ADDRESS.	FOUR PUMPING ENGINES & BOILERS	ELECTRIC CRANE	AGGREGATE AMOUNT
The Camden Iron Works Co., Camden, N. J.	$807,500.00	$9,500.00	$817,000.00
The Kilby Mfg. Co., Cleveland, O.	1— 840,850.00	10,000.00	850,850.00
	2— 840,850.00	9,500.00	850,350.00
	3— 840,850.00	8,750.00	849,600.00
	4— 837,257.00	10,000.00	847,257.00
	5— 837,257.00	9,500.00	846,757.00
	6— 837,257.00	8,750.00	846,007.00
The Holly Mfg. Co., Lockport, N. Y.	917,000.00	10,000.00	927,000.00
The E. P. Allis Co., Milwaukee, Wis.	A— 984,400.00	9,600.00	994,000.00
	B1, B2— 995,000.00	9,600.00	1,004,600.00
	C— 999,500.00	9,600.00	1,009,100.00

The plans and specifications accompanying these bids, were all much more complete and satisfactory than those previously submitted, yet all still required some modifications in several particulars, to fully meet the requirements of the general specifica-

tions. To further aid in awarding the contract, the Chief and Advisory Engineers were directed to visit the plants of the three lowest bidders to inspect the character of their work and their facilities for constructing the pumping engines. These plants were visited in January, and it was found that any one of the bidders could successfully build the proposed pumping machinery. The Camden Iron Works having proposed in writing to make any modifications or changes in their plans necessary to meet the views of the Board and their Engineers, and in conformity with the best practice, without any additional compensation, and said modifications and changes having been mutually agreed upon and incorporated as part of the original specifications which accompanied their proposal, the contract was, on January 31, 1901, awarded to that Company as the lowest and best bidder. On the same day resolutions were adopted requesting the Lane & Bodley Company and their sureties to pay into the City Treasury within thirty days after date, the difference between the amount of their contract and that of the Camden Iron Works, being $302,600.00, failing in which, legal proceedings would be instituted to recover said amount. Suit was entered in the Common Pleas Court on March 22, 1901. The case was tried and stubbornly fought in December following, the City obtaining a judgment for $238,712.00. The case was taken up to the Circuit Court on appeal. The two judges composing this Court, the third being sick and absent, could not after hearing the case, agree as to their finding, one being in favor of affirming the judgment of the lower court, the other of reversing the same. The Lane & Bodley Co. and their sureties having made a proposition for settlement on such terms as they were able to meet, which was the payment of $65,000.00 and court costs, the Court found that in view of all the facts and circumstances, the legal questions involved and of the equities of the case, that the compromise was just and reasonable, and on June 1, 1903, entered judgment to that effect. On that day the Company and its sureties paid that sum into the Treasury of the City.

The Camden Iron Works at once proceeded to modify their plans and to prepare detail working drawings of the pumping machinery, a description of which will be found in Appendix "F." Fair progress was made on this contract in the drafting room and in the foundry during the first two years, the absence of proper machine tools and of sufficient room for erecting the engines in the shop, being the main cause of any delay. Monthly estimates were granted as fast as the work in the shops progressed, which was constantly under the supervision of a resident inspector.

In the course of time a number of modifications to the contract were at the request of the contractors, made and provided for in supplementary agreements. The first, made on May 21, 1901, consisted of substituting mechanical stokers with artificial draft

for Roney stokers with natural draft. The second covered some slight changes in the specifications for boiler steel; the third, made on April 1, 1902, provided for furnishing a 20-inch steel I-beam for the support of the circular tracks for the outer end of the traveling crane at a cost of $930.00. The fourth permitted the contractors to provide and erect, subject to approval, superheaters in connection with the boiler plant, the contractors to have under certain provisions and stipulations the benefit of whatever increased duty might be obtained during the duty trial with the aid of the superheaters, the contract and specifications providing that the contractors shall be entitled to additional compensation at the rate of $1,000.00 for each one million foot-pounds which each engine shall, during the duty trial of 144 hours, develop in excess of, or above the specified duty of 115 million foot-pounds for each one hundred pounds of Pittsburg nut and slack coal put into the furnaces. The contract and specifications also stipulated that a deduction of $1,000.00 be made from the contract price for each one million gallons which each engine shall fall short of pumping 180 million gallons during said six day test trial, and also a deduction at the rate of $2,000.00 for each million foot pounds which each engine shall during such test trial develop below the specified 115 million foot-pounds. The results of the test trials will be found in Appendix "F."

Another agreement provided that the exposed surfaces of the boiler settings, flues and economizers be faced with Hanover red pressed brick, laid and pointed in red colored mortar for an additional sum of $500.00.

On June 9, 1903, the time for the completion of the first two engines was extended to April 1, 1904. On June 17, 1904, a second extension, and on June 22, 1905, a third extension for the completion of all of the engines was granted to September 1, 1906.

By July, 1903, very nearly all the foundry work was finished, over two-thirds of the castings having been machined and nearly one-half erected in the shop. In August Mr. D. Heggarty, the Superintendent of erection, came on to arrange for track facilities and to erect tools for handling the castings. Early in October spur tracks were laid. In December the work of erecting the thirty-ton electric traveling crane was commenced and on January 22, 1904, the same was ready for service.

As has been stated in another part of this report the deck of the caisson of the pump pit floor had, around the central shaft, under the influence of high stages of river and ground water, in spring of 1901, been raised 3⅝ inches above its original position, while next to the pump pit wall it had not moved after its first settling to the extent of 1½ inches. Subsequent high stages of river and ground water in the months of March in 1902 and 1903 brought the permanent position of the deck about ¾ of an inch higher, or 4 7-16 inches above its original elevation. Each material rise and fall

of the ground water above elevation 25.00 caused some corresponding movement of the deck, particularly near its center, the amount of which was determined by a series of very accurate observations.

As the time for the erection of the pumping machinery approached, the necessity of supplying some corrective remedy and of securing a level and immovable foundation became evident. In November, 1903, two plans were submitted, one by controlling the pressure under the deck during high stages of ground water by relieving that pressure by means of four ten-inch wells near the corners of the central chamber of the caisson driven with a strainer down to the rock, the area through which the ground water could pass to the area within the cutting edge of the caisson being limited. The water was to be drawn from these wells by means of electric driven centrifugal pumps to such extent as to maintain the elevation of the water or the pressure under the deck at whatever point it was desired, this being possible as the area through which the ground water could pass to the area within the cutting edge of the caisson was limited and could be still further restricted. During the erection of the pumping machinery it would be necessary to keep the stage of the ground water below elevation 18.00 and after erection, below elevation 41.00, the weight of the machinery being equal to the pressure of 23 feet of water against the under side of the deck. As the ground water does not reach this stage until the river water rises to elevation 55.00, the operation of the centrifugal pumps would not necessarily be very often nor for long periods. The other plan consisted of loading the deck of the caisson with a weight sufficient to counterbalance so much of the maximum water pressure from below as exceeded the weight of the machinery. Though the estimated cost of the former plan was $30,000.00 and of the latter was $85,000.00, the former did not meet with the fullest approval of two of the engineers. Other plans, suggestions and expedients were considered but dismissed as being either of a doubtful character, impracticable or too expensive. The plan of providing a counterweight was approved by the Board, and plans and specifications were prepared for placing 4,200 tons of cast iron on the deck in the form of a hollow cylinder concentric with the pump pit shaft, its inside diameter being thirteen feet and its outside diameter 25 feet and its height 72 feet.

On January 8, 1904, ten bids were received for furnishing f.o.b. cars at the River Pumping Station cast iron blocks, each of about six tons weight, and of such form as to permit of same being laid up in cement in the form of a hollow cylinder with smooth exterior faces. The bids ranged from $72,870.00 to $105,000.00. The contract was awarded to the Bollman-Wilson Foundry Company of Cincinnati, they being the lowest bidder, at their proposal of $17.35 per ton. The first castings were delivered on Feb-

ruary 6, and the contract completed by April 5. The final estimate amounting to $71,368.79, being passed on April 8. The blocks were unloaded and laid in position by day labor and the aid of the electric traveling crane. The joints were made of cement mortar. The total cost for labor and material was $2,823.90. The work was completed by April 15. During the month of March, and the fore part of April, the river water reached elevation 46.00 and 48.00 and the deck did not go down very much under the load. As the water receded the deck followed slowly to a limited extent. It being necessary to bring the deck down as near as it was possible to its original position before setting up and leveling the bed plates, so that the engine load could not cause any further settling of the deck, water was, on May 13, let into the pump pit at the rate of five feet per day until the water stood thirty-one feet deep. This added 6,880 tons to the weight on the deck. Under this load it rapidly lowered to within ⅜ of an inch of its original elevation. The water was left on the deck until July 7, 1904, when it was removed by pumping. The deck was cleaned and all joints recaulked. The first cars with pump castings arrived early in April, 1904, and from that time continued to come without any extended interruption, the same being unloaded and stored by the erection crew, which was being organized by the contractors. The first work undertaken was the construction and erection of the passenger elevator extending from the engine room floor to the bottom of the pump pit with landings at every gallery level, which the Camden Iron Works had included as a part of their proposition. Early in August the contractors commenced to cut off such of the anchor bolts built into the pump pit floor which would not be needed, and to place such additional bolts as were required, after which the bed plates for the four pumping engines were placed and leveled up. During the balance of the year after July, 1904, the stage of the river continued below elevation 10.00 and most of the time below elevation 7.00. Continued close observations indicated that the deck might continue to deflect under the full load of the machinery during the lowest stage of water. It was then determined to bring the deck down to its original lowest position, if possible, before proceeding with the permanent erection. To that end 796 tons of large pump castings were during the last week in October distributed over the bed plates. On November 4, water was again pumped into the pump pit until the water stood thirty-four feet deep on the floor, when the load including the counterweight amounted to 12,440 tons, with the result that the caisson deck or pump pit floor reached its original lowest position within 1-16 of an inch. During this period of loading, the water in the pump pit shaft was lowered to a point below the transverse crack in the brick lining of the shaft and one layer of brick removed so as to not allow the brickwork to interfere with the deflecting of the deck and shaft. When the deck and

shaft had reached its lowest position, the crack was closed with six 2½-inch and three one-inch threaded pipes built in to permit of cement grout being injected under pressure thereafter. By December 4, all the water was taken off the floor and the same cleaned. The castings were also removed and cleaned, and the bed plates raised, releveled and set in cement concrete and mortar. The contractors were then urged to expedite, while the river was at its lowest stage, the erection of the engine frames, pumps and water ends up to the level of the upper bed plates and complete such before the river would rise to its usual stage of high water in February, it being the intention to prevent the floor from rising thereafter by letting in enough water to counter-balance the excess upward pressure at each successive rise of the ground or river water until the erection of the machinery had been completed. In order to closer observe the stage of the ground water, a six-inch well was sunk to a depth of 90 feet, outside of and about 40 feet south of the engine house. Notwithstanding the assurance to the contractors, that they were not responsible for the engine foundations and of their written promise of August 1, 1904, that they would proceed with the erection of the engines with all possible speed, the erection work dragged along, and instead of assisting in prosecuting the work in such a manner as to facilitate the control of the floor, they were constantly impeding the same, apparently with the view of exploiting the existing conditions. During January and February the contractors were finally prevailed on to erect the lower frames and pump castings of the four engines in place. As the river water was getting above elevation 40.00 water was, on February 27, 1905, let into the pump pit until it reached a depth of 15 feet, which did not, however, interfere with the erection, as the work was considerably above that point. The water was in April gradually let out as the ground water fell. Similar action was taken during the third week in May, when the river water rose above elevation 50.00, only ten feet of water, however, was put onto the floor; and no movement exceeding 1-32 of an inch took place.

In order to avoid this method of preventing the floor from springing again, a supplementary agreement was on May 23, 1905, entered into with the Camden Iron Works, whereby they were to promptly place temporarily in position upon the lower set of engine frames of each pumping engine the pillow blocks, shafts, and all of the engine frames and cylinders above the pillow blocks, without lining or leveling the same, and after the effect upon the bed plates at low stage of river water had been observed, to remove the parts of one engine, temporarily placed above the top of the water end frames, and erect the same permanently before taking down the loosely placed parts of the next engine, thus successively erecting each pumping engine permanently in place, all of the work of placing temporarily and taking down to be paid for at cost plus 15

per cent. The work of erecting the four engines temporarily was completed by August 1, 1905, placing a weight of nearly 4,000 tons of machinery on the floor. During this period and the months following, the stage of the river water fluctuated from elevation 9.00 to 50.00, without causing more than 1-40 of an inch of movement in the floor. After the temporary erection was completed the contractor's force resumed work on the erection of the discharge mains, condensers and valves and continued so until August 31, when all work on the part of the contractors was by them arbitrarily suspended, although permanent erection of all work beneath the pillow block level could have been continued.

At this time the contractors assumed the attitude of claiming that the caisson deck or pump pit floor did not afford a proper foundation and of criticising the methods adopted to control the movement of the same, and declined to proceed with the permanent erection and completion of the pumping machinery unless they were fully protected against loss or damage arising in the course of construction or affecting the efficiency of said machinery during the test run or the year of probation, resulting from the lack of stability and sufficiency of the foundation or deck. Accordingly on January 10, 1906, a supplementary agreement was entered into with the Camden Iron Works, whereby it was agreed that if they will proceed without further delay in the erection of the pumping machinery, in accordance with their contract, they shall have reserved to them all rights and claims for any losses or damages resulting from the above-mentioned causes.

As this again brought the permanent erection into that period of the year when there would be considerable fluctuations in the stage of the river and ground water, it became necessary, in leveling up the top of the water end frames for the pillow blocks, after the castings above that part of any one engine had been removed, to take into consideration the existing stage of the ground water and the amount and distribution of the weight of the pumping engine above said point, so that when said engine was completely erected said bearings would, at lowest stage of ground water, be in a perfect plane, with the front end 1-100 of an inch lower than the rear end, to compensate for the possible upward movement of that part of the floor, during the high stage of ground water, in excess of that part nearer to the pump pit wall. The continuous extremely minute and accurate observations which had been made enabled such determinations as to the different elevations of various points of the tops of the water end frames to be made and the perfect results obtained, verified since by observations made with the machinery in operation during periods of fluctuation varying from the lowest to the second highest stage of river water on record, show the perfect workmanship

employed in leveling off said water ends to the warped surface elevations carefully determined upon. The temporarily erected parts of engine No. 2 were at once taken down and the same then permanently erected, this work being nearly completed in May. In that month the contractors again suspended all work because an order to proceed with the permanent erection of the next engine had not been given in writing. They were urged to proceed with all possible speed in getting two or at least one of the pumping engines and the boiler plant ready for service, as the conditions due to scarcity of water in the city were becoming more serious every day. The erection of the eight boilers and appurtenances was commenced by the Stirling Company for the Camden Iron Works as early as September 12, 1904, still there was quite an amount of detail work not completed. Promises were made at different times to rush the work, but it was not until September 18, 1906, that engine No. 2 was started for the first time, running a few hours on that and the following day, the water being wasted. In October the pump operated a number of days delivering water direct into the gravity tunnel, thus supplying water to the pumping engines at the Main Pumping Station in the city. On October 29 water was for the first time delivered into the clear water basin and from there into the tunnel, and on December 10, 1906, the water was delivered into Settling Reservoir No. 1 for the first time.

On January 1, 1907, this pump was placed in regular commission of supplying water, but not without continuous protests from the contractors because of the possibilities of damage to the machinery or of the risks they were incurring in operating the same, going so far as to state that they were unwilling to continue operations unless it was agreed that a commission of three engineers be appointed to determine from the plans for the pumping engine what foot-pound duty such engines can be expected to produce, making allowance in their award for the effect of the superheaters they had furnished, the result of the superheaters to be determined by their value as shown in other installations, and further that immediately upon each engine proving it has the contract capacity of thirty million gallons, a settlement shall be made in full for the same together with one-fourth of the bonus that the whole plant will be entitled to, as may be determined by the decision of the Board of Engineers, thus dispensing entirely with the duty test and the year of probation provided for in the contract. Such absurd propositions were, of course, not acceded to, but resulted in a supplementary agreement under date of April 18, 1907, wherein it was stipulated that as rapidly as said Camden Iron Works shall have completed, ready for continuous operation, any one of the four pumping engines, and shall have notified the Board of such completion, the Board will fix the beginning of the year of probation of such pumping engine as from the day

such pumping engine shall have been so completed, and that said Camden Iron Works shall have the right to make the test run of any pumping engine at any time within the year of probation, when it may have the machinery ready for such test, without awaiting the completion of any other part of the work, and that the contractors be reimbursed the wages plus 10 per cent of any of their employees who are engaged in operating the machinery and supplying water to the City.

Engine No. 2 was maintained in regular commission during all this controversy, and up to the present time, except for a period of six weeks during September and October, 1907, when the steam end was dismantled to take out the intermediate steam cylinder head, which was cracked at the time when steam was first turned into the engine. The cylinder head was sent to the works in Camden, a new one cast and machined as an exact duplicate of the original. The cylinder was put in place and the pump put back into commission on October 14.

When, on May 16, 1906, the permanent erection of engine No. 2 had proceeded sufficiently to have fully 1,200 tons of material in place, the parts of engine No. 3, which had been temporarily erected above the water ends, were removed and permanent erection proceeded with exactly as in the case of engine No. 2, and the erection of engines Nos. 1 and 4 were proceeded with in like manner. Engine No. 3 was placed in commission on April 28, 1907, No. 1 on May 9, and No. 4 on August 13, 1907, all of the machinery operating very smoothly and without excessive vibration, and have alternated in supplying the required amount of water. The superheaters were erected between the batteries of boilers in September, 1906, but were not put in service until November 20, 1907.

The Ohio river rose in flood stage to elevation 67.54 at noon on January 21, and to 64.80 on the morning of March 16, 1907, the ground water at the pumping station reaching 57.80 on January 23 and 54.96 on March 21, or respectively 76 and 73 feet above the bottom of the caisson deck, producing an upward pressure against the bottom of the structure of over 30,000 tons. Hourly observations of the stage of the ground water were taken for a period of ten days during each flood, together with daily records of the behavior of the deck and of the bed plates of the several pumps, and it is gratifying to state that the upward movement of the deck during either flood did not exceed 1-25 of an inch, which did in no way interfere with nor affect the perfect, smooth running of all the pumping machinery. Since then a concrete floor 12 inches thick has been laid on top of the deck timbers and between the engine bed plates, with suitable drainage facilities towards a small sump to take care of the plunger and other leakages. No chance of any kind, however, should be taken when the ground water

reaches such a high stage and when that stage exceeds elevation 56.00 water should be let in onto the floor at the rate of one and one-half foot for every one foot of rise above elevation 56.00, and as a precedent in cases of other floods, 3.37 feet in depth of water was let in on the floor on January 23 and removed as the ground water receded. As these extreme floods do not average more frequent than perhaps once in fifteen or twenty years, this slight inconvenience is of no importance.

As the contract provides that the capacity and duty tests of each engine, of not less than 144 hours duration, shall be made at a stage of water in the river not exceeding twenty feet above low water, preparations were made to start these tests early in July, 1908. The contractors, however, were not ready with the machinery, and the same was postponed until September 1, 1908, when the test of No. 3 engine was commenced and completed on September 7. The test of Engine No. 4 was commenced on September 16 and ended on the 22d. Both of these tests were made with saturated steam. As the amounts which the contractor should finally be paid for these pumping engines depended upon the duty which they would develop with superheated steam, it was decided to make the next two test runs with the superheater in service. Accordingly the test of Engine No. 1 was made with dry steam, and commenced on October 5 and ended on the 11th. The second test with superheated steam was made with engine No. 3, being one of the two most removed from the steam plant. This test was made from October 27 to November 2. As all of the engines tested showed very nearly the same efficiency, a capacity test only was made of engine No. 2.

The conditions under which the superheaters were installed provided that after the tests the engines were to be operated with superheated steam for the period of one year to determine the permanent efficiency and their freedom of causing any extraordinary expenses, and that if the same was satisfactorily maintained, the bonus, if any, on each engine shall be paid on the basis of the duty obtained by the use of superheated steam. During the tests the temperature of the steam at the engine was increased 96 degrees Fahrenheit, which is higher than what was maintained during the period in which the superheaters were in service previous to the test.

The final payments therefor can not be made until the conditions as to the year of probation under superheated steam have been complied with.

The data of all these tests will be found in Appendix "F." The total cost of this work under the several contracts was as follows:

Under the Lane & Bodley contract	$1,166.79
Under the contract with the Camden Iron Works, which includes all work done under Supplementary Aggreements	818,430.00
For extra labor and material furnished as per Supplementary Aggreements	6,168.30
For extra labor and supplies furnished previous to May 29, 1905	3,886.22
For change in spiral stairway	557.25
For services of engineer during year of probation, as per contract	3,000.00
For bonus earned under the contract during test trials with saturated steam	149,448.09
For bonus earned under the contract during test trials with superheated steam	47,905.23
Total cost	$1,030,561.88

The contractors have presented claims in excess of this to the amount of $86,766.30, of which $57,000.00 represents interest on account of delay in the work; $16,899.40 for additional bonus; $4,000.00 for additional expense of erecting the pumping engines in seriatim, and the balance for additional labor and other expenses.

No final adjustment of the claims has yet been arrived at, nor has all of the above amount been paid, as the painting of all the pumping engines has not yet been completed nor the bound set of detail drawings, as called for by the contract been delivered.

The large gate valves on the pump mains and the gate valves at the weir being provided with electric motors so that they might be opened and closed quickly, and without manual labor, and as the current necessary for operating these motors was to be generated at the River Pumping Station, it was concluded to put in an electric generating plant of sufficient capacity to supply current not only for operating these valves, but also to operate machinery, pumps and valves of the filter plant and the reservoirs, and also to light the grounds and all the buildings connected with the New Water Works east of the Little Miami River. A careful study developed that the maximum amount of current so needed would require generators of 300 kilowatt capacity.

Specifications were prepared for furnishing and erecting three units of electric generators, each of 150 kilowatt capacity, direct connected to steam engines, the same to be installed together with a suitable switchboard provided with all necessary instruments and wiring in the annex of the River Station.

On February 23, 1906, thirteen bids were received, varying from $28,742.55 to $41,371.00. Three of these bids covered furnishing engines of a condensing turbine type and the others for vertical reciprocating compound condensing engines. Each bidder was required to guarantee the limit of steam that would be required to deliver one kilowatt of electric current at the switchboard. The proposal of the lowest bidder provided for three units of DeLaval steam turbines, each driving two 75 K. W. four-pole Crocker-Wheeler generators by means of a pinion on the main shaft and two gear wheels directly

connected to the generators, the latter to operate at 900 revolutions per minute, and included specially large condensers, guaranteeing a vacuum of 27 inches. This proposal was also the best so far as guaranteed economy of steam was concerned. The contract was therefore awarded to Dravo, Doyle & Co., of Pittsburg, Pa., at their bid of $28,742.55.

On April 27 a supplementary agreement was entered into which provided, at an increased cost of $1,700.00, for substituting two condensers of 25 per cent greater cooling surfaces with two crank and flywheel double-acting air pumps of the Mullan type, guaranteeing to maintain 28 inches vacuum under full load condition, and providing also for more specific compliance with the contract and test requirements.

The work progressed sufficiently to permit of one or the other generators being placed in service by the end of the year for the purpose of lighting the River Station, of furnishing power for operating the tunnel pump and to furnish light and power for the filter plant as soon as required. The capacity and efficiency tests were postponed, however, until October 30 and 31, 1907, when they met all guarantees and contract requirements. The final estimate was made on May 22, 1908, the total cost amounting to $30,353.65.

On November 2, 1906, eight bids were received for furnishing a thirteen-duct conduit from the River Pumping Station to the head house of the filter plant, and for installing therein twelve lead-covered cables, each of one million circular mills capacity with connections to switchboards; also, for ten manholes, six steel lamp poles and arc lamps along the levee, with motor circuits and connections and other work and material. Four of these bids proposed to furnish cables not in conformity with the specifications; the other four bids varied from $58,101.75 to $62,200.00. At the same time five bids were received for installing electric lighting and wiring for the pumping engines and also for the buildings and grounds at the River Pumping Station and the Intake Pier. These bids varied from $5,701.75 to $8,124.00. The Sackett Mine Supply Co., of Columbus, Ohio, being the lowest bidder in each case, the contract for the entire work was awarded to them. The lighting of the buildings and grounds at the station and of two of the pumping engines was to be completed by January 1, 1907, and the balance of the work by May 1, 1907. The work was commenced late in 1906, and was continued within the buildings during the winter months. The conduit work was started as soon as the weather permitted and pushed along energetically up to where the unfinished work in front of the head house prevented its further progress. For a time a temporary pole line to the head house provided power for trying and operating some of the machinery. As soon as the grading had been done under another contract, the work of laying the con-

duits and installing the cables was resumed and promptly completed. After the cables were installed and connected up they were subjected to a careful test and found to comply with all the specified requirements.

The time for completing this work was extended several times, the final extension being to September 10, 1907. The work was accepted, and the final estimate rendered on November 15, 1907, $500.00 being retained as a guarantee to keep the work in perfect repair for a period of six months after acceptance. Final payment was made on June 30, 1908. The total cost of this work was $63,803.50.

On November 2, 1906, five bids were received for installing all necessary wires, lamps, poles, fixtures, and other material for lighting the grounds, valve chambers and houses, shaft houses, weir houses, and other buildings, and the power circuit for all the valve and pump motors in the valve, shaft and weir houses, with all switchboards and other material. These bids varied from $10,427.00 to $15,900.00. The Beattie Electrical Company, of Cincinnati, being the lowest bidder, the contract was awarded to them. Work under this contract was begun early in the summer season of 1907, and, excepting that part of the work around Reservoir No. 2, which could not be proceeded with because of the then uncompleted condition of the reservoir, was completed by the end of that season. In October, 1908, the reservoir work had progressed sufficiently to permit the contractor to resume the work, but he was not able to complete the same, as the two light poles in front of the caretaker's house could not be erected until the railway track had been removed. He was released of so much of his work, and the sum of $109.71 deducted from his contract price. Final payment was made on January 15, 1909.

FILTRATION PLANT

Following the report upon the best method of filtering the Ohio River water, submitted by your Chief and Advisory Engineers on January 12, 1900, many propositions and schemes for purifying or filtering the river water were from time to time and by different parties presented to your Board, all of which were duly investigated and reported upon. Filter companies urged the adoption of designs and plans prepared by them, some of which had been adopted in the construction of some recent filter plants. These companies were very anxious to prepare plans or to act in an advisory character in connection with the proposed filter plant, with the view of later securing the contract for its construction. Several filter plants were visited and found to possess more or less unsatisfactory features.

Your Board having adopted the mechanical or American system for filtering the water, it was determined to conduct a series of experiments and original studies, independent of any existing or proposed design, to develop such details as would produce the best results, such as the best form of filter, the kind of strainer to be employed, what protection the gravel afforded against sand passing through the strainers, to what extent the gravel was disturbed during the process of washing, to what extent the sand worked down into the gravel, the best appliances for washing the sand and other questions which arose in connection with the design of the filter plant.

Early in 1902 a small filter with wood sides and bottom was constructed and operated as if in regular service, the water being settled and then treated with a solution of sulphate of alumina. All the different strainers on the market were tested, also the various methods of mechanically agitating the sand during the periods of washing, some of which proved themselves as entirely unserviceable, and none of which were free of objection.

In the summer of 1903 a second experimental filter was constructed and operated at the Laboratory, its sides consisting of glass panels which permitted an ocular study of the effect of the various experiments that were made. An air compressor was also installed, and air and water were separately and conjointly introduced in various ways and under different pressures to agitate and wash the same. Different strainers, sizes of pipes and air openings were used, and the action of the air and water in passing separately and conjointly through the gravel and the sand was carefully noted. Many curious

effects were observed during the experiments, some of which had a direct bearing upon the objects of investigation. These experiments were continued until late in 1904, and resulted in determining the best form of strainer plates and sizes of openings, the proper depth and sizes of gravel and sand, the most effective head of the wash water at different points to bring the sand into complete flotation, the most suitable size and material of wire cloth to retain the gravel in place during washing, and the proper distance between the top of the sand and the wash-water weir to prevent loss of sand. Experiments were also made in using sulphate of iron and lime as coagulants, and the best way of converting these into suitable solutions and of introducing same into the raw water.

A number of experiments and tests were also made to determine the value of various mixtures used with cements or upon cement mortar facings to render concrete impervious to water, with the result that Portland cement mortar and concrete of very soft consistency thoroughly churned with thin blades of steel and well rammed was used with excellent results.

All of the information thus obtained, much of which will be found in condensed form in Appendix "C," was used in preparing the plans, details and specifications of the filter plant. The work of constructing the various parts of this plant and of furnishing material for the same was divided up into fourteen different contracts, only two of which may be said to cover construction work, the others being for the delivery of material, such as cast-iron pipe and special castings, gate and sluice valves, steel pipe, strainer plates, filter sand, and other material, and for furnishing and installing operating machinery.

The first work advertised in connection with the Filter Plant was for the furnishing and delivery of cast-iron pipe and special castings for the coagulating basins, the filters, and the clear-water basin, and also included a little over 9,031 tons of 48 and 60-inch straight pipe and 240 tons of special castings for the two pump mains leading from the Main pumping station on Eastern Avenue. The pipe for the Filter Plant consisted of 3,297 tons of straight pipe and 1,155 tons of special castings, varying from 4 to 60 inches in diameter, the special castings numbering 2,986 pieces. In the specifications for this and subsequent cast-iron pipe contracts, the different sized pipes were divided into classes according to the pressures to which they were to be subjected and the thickness computed upon the higher grade of iron specified, as a result of which the tonnage from standard weights was reduced fully 20 per cent without impairing the service of the pipe. The interior of the pipe was cleaned by sand blast, which insured a perfect and

complete coating of the metal when dipped as well as a somewhat smoother surface without adding more than $1.00 per ton to the cost of the pipe.

On March 17, 1905, but one proposal was received for furnishing this pipe, being that of the U. S. Cast Iron Pipe & Foundry Co., whose bid was $25.90 per ton for straight pipe of all sizes, $85.00 per ton for 48 and 60-inch pump main specials and for flange specials below 30 inches diameter, $80.00 per ton for specials of all sizes excepting for the pump mains, $90.00 for flange specials of 30 inches and above, $97.50 per ton for miscellaneous castings, and $1.00 per ton for cleaning pipe and specials above 24 inches by sand blast and $2.00 for sizes below 30 inches, with an allowance of $10.00 per ton for all specials not subjected to a hydraulic pressure test. The contract was awarded on the above proposal. The first pipe for the filter plant was delivered in November, 1905, and the delivery continued during the winter months, fully 80 per cent being delivered by May 1, 1906, and practically all of the material being delivered by December 1, 1906. The final estimate was submitted on May 31, 1907, and for this part of the contract amounted to $179,760.04.

On July 28, 1905, three bids were received for furnishing and delivering electrically operated sluice and gate valves for the Filter Plant and mud valves for the coagulation basins. The contract for the sluice valves and the 48 and 60-inch gate valves was awarded to the Coffin Valve Co., and that for the Filter House gate valves and the mud valves was awarded to the Fairbanks Company, of New York City.

Under the former contract and a supplementary agreement thereto, by which some valves were dispensed with and others added, eleven 84-inch, two 60-inch, one 30-inch and one 24-inch sluice valves and six 60-inch and one 48-inch gate valves were furnished for the Filter Plant, all of which were equipped with electric motors and motor stands, as well as hand operating gear. In addition thereto some 44 valves, varying from 4 to 36 inches in diameter, were furnished for the Filter Plant. Delivery was commenced on November 19, 1905, and the contract practically completed by the end of 1906, though the final payment was not made until in 1908 on account of some claims held against the company by a local firm who attended to the wiring up of the motors. The total amount of the contract chargeable to the Filter Plant was $31,921.00.

The contract with the Fairbanks Company covered six 36-inch, fifty-six 30-inch, fifty-six 24-inch, twenty-eight 20-inch gate valves and six 20-inch mud valves. All of these gate valves are in the Filter House, and are provided with electric motors and floor stands. The motors are wired to a common switchboard for each filter, and are provided with limit switches, which shut off the current as the valve approaches the limit of its travel either way. The delivery of the valves was commenced in December,

1905, and completed in July, 1906. On account of making good some defects in the valves, which was promptly attended to by the company, and of adjusting the limit switches, the final payment was not made until July 14, 1908. The total amount of the contract was $73,324.00.

On August 25, 1905, bids were invited for the construction of the filters, coagulation basins, and clear-water basin, together with all necessary piping, valve chambers, and other miscellaneous work in connection therewith. This work did not include the Head House, Chemical House, nor the Filter House above the Filter House floor or the Valve Houses above the valve chambers, but did include all earth work, the broken stone, concrete, asphalt, burlap, and brick revetment of the four basins, the construction of twenty-eight concrete filter tanks upon a concrete groined arch foundation, with all connecting piping, valves, strainer system and filter gravel and sand in place, the laying of all cast-iron and steel mains connecting the settling reservoirs with the filter plant and the coagulation basins with the filters and the clear-water basin; the building of concrete valve chambers, of laying flush, overflow and drain pipes, and of grading and sodding the grounds.

The basins were formed partly in excavation and partly in embankment, and their construction, including the revetment, was similar to that employed on the settling reservoirs.

The filters are divided into four groups of seven each, by the pipe gallery, which is 28.5 feet wide on top, 23 feet deep, and 492.5 feet long, and the central gallery 20 feet wide across from east to west. The pipe gallery extends from the Head House on the south to the Chemical House on the north, and its sides, as well as those of the middle gallery, are formed by the walls of the filters and their foundations. The filters are independent, rectangular, re-enforced concrete boxes, 52 feet long by 33 feet 8 inches wide and 10 feet 9 inches high on the outside. They are supported by a vaulting of groined arches 7 feet high above a groined arch floor, forming chambers, which contain all the effluent piping of the filters, and all of which becomes thereby accessible. This effluent piping begins with 112—3½-inch collector pipes, which extend downward through each filter bottom from the concrete collection channels in each filter, and discharge into 10-inch pipes, which gradually enlarge into two 28-inch mains at the pipe gallery, where they unite and connect with the wash-water pipe as well as with the 60-inch effluent main. To prevent the roof vaulting and the floors of the filters, which rest upon it, from cracking and leaking, the vaulting was re-enforced with ⅝-inch steel rods placed 12 inches apart both ways.

The side walls of the filters are 10 and the end walls 12 inches thick. Each filter is divided into two sections, of 14 by 50 feet each, by a channel or central gutter three feet wide inside, with walls six inches thick, extending from the bottom to the top of the filter, where the same is covered. The walls of this channel are tied to the opposite walls of the filter by means of three walks 3 feet wide, leaving the entire balance of the top of the filters exposed to view. Upon the flat bottom of the filter is placed the strainer system, which consists of twenty-eight longitudinal rows of perforated curved brass plates, spaced 12 inches apart on centers covering that number of concrete channels 3 inches deep and 2½ inches wide, which are tapped by the 112—3½-inch collector pipes. The filter bottom forms the bottom of these channels, while the sides of the channels are formed by concrete walls, which are topped off in wedge-shaped ridges 9 inches high and 2 inches wide on top. The bottom of the ridge sets back ⅜ of an inch, leaving a shoulder for the support of the strainer plates where they are imbedded in cement mortar. Upon the strainer plates, and filling the space between the wedge-shaped ridges, four layers of graded gravel are placed, the bottom layer varying from ½ to 1 inch in size and the top layer varying from 1-12-inch to ⅛-inch in size, the top layer being rounded off slightly above the top of the ridge. The top of the gravel is covered and held in place by strips of brass wire cloth 26 inches in width by 50 feet in length, tightly stretched and firmly secured by brass anchor bolts built into the ridges. The sides of the strips where they lap are tacked together with copper rivets every 6 inches for their entire length. Upon this wire cloth the bed of filter sand 30 inches in depth is placed.

Each half of the filter is crossed by six lateral gutters opening and draining into the central gutter or channel. These lateral gutters have "V"-shaped bottoms, are made of re-enforced cement mortar, and are 14 inches wide, from 9 to 19 inches deep and 14 feet long. They are spaced 8 feet 4 inches apart between centers, and have their edges finished off on a true level 30 inches above the top of the sand bed. Their purpose is to weir off the dirty wash water and discharge the same into the central gutter and thence into the drain. They also admit the raw water during the process of filtering.

Five valves control the flow of water to and from the various mains in the pipe gallery for each filter, all of which are operated by electric motors controlled by switches located on one board. The switchboards are located upon the Filter House floor, and are grouped together for each pair of adjacent filters, placed four feet apart and face the filters to which they belong. Between the front end of each group of switchboards a table is placed with marble slab, bowl, and back. Above the bowl two ½-inch faucets furnish filtered water from each effluent main of the two adjacent filters by means of electrically operated centrifugal pumps on the floor below. An indicating dial on each side

of the bowl shows the loss of head of the water in passing through the filter and also the height of the water on the filters and that in the effluent pipes.

On September 29, 1905, five bids were received for this work, which were as follows:

NAME OF BIDDER AND ADDRESS.	AGGREGATE AMOUNT.
Keeling & Ridge Company, Pittsburgh, Pa.	$464,050.00
The Kirchner Construction Co., Cincinnati, O.	487,565.75
W. J. Gawne Company, Cleveland, Ohio.	488,112.50
Ferro-Concrete Construction Co., Cincinnati,O	510,025.00
Pittsburgh Filter Manufacturing Co., Pittsburgh, Pa.	514,884.65

In the proposal of the Keeling & Ridge Co. it was found that the bidders had crossed out Paragraph "R" of the contract and had substituted in writing the words, "A time to be mutually agreed upon," thereby making their bid informal. This paragraph referred to the liquidated damages to be deducted in case the contractors failed to complete the several parts of the work within the time specified, providing such delay is not caused by any failure on the part of the Trustees. As the time within which the several parts of the work, embraced in this contract, were to be completed, was considered an essential element thereof, the elimination of said paragraph from said contract prohibited the consideration of said proposal. It had become apparent that it might become necessary to assist the old works in supplying water to the city before the new works had been entirely completed, and therefore to be able to do so as soon as it was possible, it was stipulated in this contract that certain parts of the work must be completed in advance of other parts, so that water might be delivered from the River Pumping Station to the inlet shaft of the gravity tunnel while the balance of the work was in process of construction. The contract was therefore, on October 24, 1905, awarded to the next lowest bidder.

The contractors immediately commenced work by bringing their equipment upon the ground and starting the excavation, as well as laying pipe. Work continued throughout the winter months whenever the weather would permit. With the opening of the working season some delay was experienced on account of the scarcity of men, which condition continued all through the summer.

On June 12, 1906, the amount of 12 and 24-inch pipe to be laid under the contract was increased, respectively, by 245 and 1,425 feet. The 60-inch pipe lines, the 84-inch steel pipe line and valve chambers "B," "E," and "D" were completed early enough to permit of the first water, which was pumped at the River Station on September 18, 1906, to be discharged through a 24-inch by-pass and these valve chambers into the steel pipe line. The first water pumped was wasted. On October 6 the water was by-passed to the tunnel, and one of the high-service engines at the Main Station began to deliver water

into the hilltop district. As this service, without any opportunity for storage between the pumping engines contained an element of risk, as it required the engines at both stations to start, operate and stop in unison with each other, the work on the clear-water basin was crowded forward as much as possible. On October 29 it had progressed far enough to permit of the lower part being used for storage, into which the pumps at the River Station could discharge, or from which through the gravity tunnel the pumps at the Main Station could be supplied. Early in December this basin was entirely completed, and the same has been in service ever since. The urgency for this basin somewhat retarded the other work under this contract, but the necessity of keeping in advance of the contractor for the superstructures constantly crowded the contractors to push this work as rapidly as possible in keeping with good work. As it was, the work was delayed by not having the forms for the filters sufficiently advanced to rush the concrete work as it should have been, and this caused some delay to the contractors who followed them. In December, 1906, the contractors asked for an extension of time within which to complete the coagulation basins, which was granted, and the time for the last basin was extended to July 1, 1907. The south filters were not sufficiently completed to permit the contractors for the Filter House to proceed until early in July, 1907. Some delay was caused by the non-delivery of the wire cloth on the part of another contractor within the time specified. This delay prevented the laying of this wire cloth over the gravel and of placing the filter sand at a time when it was most convenient in the regular progress of the work. All of the work in connection with the filters, excepting the placing of the wire cloth and sand was completed by the first week in October, and all work under the contract was finished by December 20, 1907.

In March, 1908, a final estimate of the amount of work done under the contract was prepared and submitted, the amount being $494,297.91. At this time the contractors filed a bill of nineteen claims for damages on account of delay caused them by various other contractors. This was offset by a claim of similar nature filed against them in behalf of other contractors, and in consequence of delay in placing the filter plant in service. After giving these claims a long period of consideration, it was finally mutually agreed that in consideration of the contractors waiving all claims for damages or extras under this and all other contracts with your Board in which they are interested, the city would relinquish its claims for delay or damage under this contract, and pay the retained five per cent at the expiration of the year of guarantee, providing the contractors had within that period repaired all defects which might develop on account of poor material or imperfect workmanship. The final payment of $24,714.90 was made on February 2, 1909.

In connection with this work several contracts were let for the furnishing of material required in the construction of basins and filters aside from the cast-iron pipe and valves already referred to.

On November 10, 1905, three bids were received for furnishing and delivering 1,521 feet of 84-inch diameter riveted steel pipe, one 84 to 60-inch steel reducer, and one 84 by 60 by 60-inch steel "Y" branch, with curves, heads, cast-iron nozzles, steel flanges, and other appurtenances for the filtration plant. These bids also included furnishing for the two settling reservoirs four 50⅜-inch diameter floating tubes, each 39.5 feet long and each provided with a steel plate float 66 inches in diameter and 9.5 feet in length. The bids varied from $42,132.00 to $46,148.00. The contract was awarded to the Riter-Conley Mfg. Co., of Pittsburg, Pa., they being the lowest bidders. Part of this material was to be delivered by April 1 and the balance by June 1, 1906. The steel pipe and specials were delivered in advance of the time specified, and the floating tubes within the time called for. The final estimate was not paid, however, until April, 1907, when all the piping had been tested in place. The cost of the work for the filtration plant was $37,250.00 and for the floating tubes, $4,882.00.

On February 23, 1906, three bids were received for furnishing and delivering 3,150 pieces of 3½-inch diameter flanged cast-iron pipe castings. These pieces were 21 inches long and serve to collect the filtered water from the concrete channels below the strainer system and to deliver the same into the 10-inch collector pipes. These bids varied from five to twelve cents per pound. The contract was awarded to the U. S. Cast Iron Pipe and Foundry Company, they being the lowest bidders. These castings were delivered practically within the contract time, and the final estimate was allowed on October 12, 1906, in the amount of $4,827.42.

On June 22, 1906, three bids were received for furnishing and delivering 13,400 pieces of perforated, curved brass plates, 28,700 ¼-inch brass anchor bolts, nuts and washers, and 38,500 ¼-inch brass hook bolts, nuts, washers and cross rods, all of which constitute the strainer system for the twenty-eight filters. These strainer plates, covering a length of over seven and one-half miles of concrete channel are of 1-12-inch brass plate 3½ inches wide, and are perforated with four rows of holes, 3-32 of an inch in diamter, spaced ¾ of an inch between centers. These plates rest upon a shoulder on each side of the concrete channel, and are held in place by brass hook bolts from brass cross rods anchored in the walls of the concrete channel, and support the graded gravel. The anchor bolts are built into the top of the concrete ridges, and hold the brass wire cloth which confines the gravel in place.

Two of the three bids received were informal, as they covered only a part of the material required. The contract was therefore awarded to the Greer Filter Company, of Philadelphia, who were the only formal bidder, at their proposal of $17,190.00. All of this material was delivered within the time specified, April 1, 1907, and the final estimate was paid on April 23, 1907.

On June 22, 1906, six bids were received for furnishing and delivering 400 rolls of brass wire cloth, each consisting of a strip 50 feet in length and 26 inches in width, with selvage on both sides. The cloth consists of No. 20 gauge brass wire accurately and uniformly woven at right angles to each other, forming 100 meshes to the square inch. This wire cloth is placed over the graded gravel, which is packed above the strainer plates and between the concrete ridges, and holds the gravel in place during the periods of washing the filter sand. The edges of adjoining strips are fastened to each other by rivets, and the cloth is held in place by brass nuts and washers to bolts anchored into the concrete ridges, the filter sand resting upon the cloth.

The bids varied from $10,399.00 to $15,500.00. The contract was awarded to the Michigan Wire Cloth Co., of Detroit, Mich., they being the lowest bidder. The contract called for a delivery of half the number of rolls by October 15, 1906, and the entire number by April 1, 1907. Considerable trouble was experienced from the very beginning in receiving this material on account of the freight being prepaid for only part of the way and of it being consigned to other than the specified locality. By January, 1907, there were 163 rolls received. On March 15, at the request of the contractors, the time for delivering all the wire cloth was extended to June 1, 1907. On May 31 the time was again extended, half of the amount required to be delivered by July 1 and the balance by August 1, 1907. Even these conditions were not met, and the contractor for the construction of the filters was hindered in completing the last half of the filters. Frequent appeals, requests and demands to proceed with the delivery of the material elicited no satisfactory response from the contractors. Only by constant wiring and notifying them of the damages caused to other contractors by their delay was it possible to obtain this material in small lots. Not much more than half of the total quantity was received by August, and the last was not received until November 26, 1907. On account of this very unsatisfactory delivery, claims for damages were filed by the contractors whose work of completion was thereby delayed. These claims were duly passed upon and finally adjusted. In the consideration of these claims it was found that the actual cost of placing the wire cloth and sand in one-third of the filters had been increased by about $250.00 on account of the late delivery of the cloth, and this sum was therefore deducted from the final estimate, which was paid on January 6, 1908. The total amount paid under the contract being $10,149.00.

After some correspondence with the parties engaged in supplying filter sand, and after a careful physical and chemical analysis of Ohio River sand as obtained from several dealers in the city, it was found that a good and very satisfactory filter sand could be secured by screening and washing the sand obtained from bars in the Ohio River above the Little Miami River. In preparing the specifications for filter sand and gravel, bids were invited for selected Ohio River sand and gravel as well as for standard filter sand and gravel. The limitations of the latter in both size and character were closely defined, and the quantities required were 4,000 cubic yards of filter sand, 95 cubic yards of gravel, Class "A," 130 of Class "B," 190 of Class "C," and 250 of Class "D," while the quantity of river sand required from which to obtain the amount of standard sand by screening and washing was estimated at 7,000 cubic yards.

On October 13, 1905, the following bids were received:

Name of Bidder and Address.	Material.	Amount
Donnelly & Dovey Const. Co., Cincinnati, O	Standard Filter Sand	$12,000.00
Diamond Bluff Filter Sand Co., Keokuk, Ia	Standard Filter Sand	31,779.00
J. R. Ware & Son, Cincinnati, O	River Sand	8,750.00
Smith Sand Company, Cincinnati, O	River Sand	17,150.00
J. R. Ware & Son, Cincinnati, O	Gravel, Class "A" & "B"	370.00
Donnelly & Dovey, Const. Co., Cincinnati, O	Gravel, "A" & "D"	1,835.00

The samples which accompanied both of the Donnelly & Dovey Construction Company's bids showed that nearly one-half of the sand and gravel consisted of soft limestone, hence was not suitable nor under the specifications acceptable. The bid of the Diamond Bluff Filter Sand Company was informal, as it was not accompanied by any bond or check. The samples of Ohio River sand submitted by J. R. Ware & Son and the Smith Sand Company complied in every respect with the chemical requirements of the specifications. On examination it was found that the former by screening and washing produced 57.16 per cent of standard filter sand, and the latter 62.59 per cent. It was further ascertained that the screenings contained enough of the finer gravel to supply the required amount of Classes "C" and "D." The contract was therefore awarded to J. R. Ware & Son at their bids.

The delivery of this material was commenced in April, 1906, the sand being delivered on top of the Little Miami River bank near the Filter Plant. The delivery continued as wanted until 6,266 cubic yards of river sand or a sufficient amount of filter sand and graded gravel had been secured. The final estimate was allowed October 15, 1907, the same amounting to $8,482.67.

The grading of the gravel into four classes, varying in size from 1-12-inch to 1 inch and the screening and washing of the sand was done by day labor. The gravel was

graded by rolling screens having the proper size openings. The sand was mixed with water and thrown upon an inclined sheet of perforated steel which sifted out the coarser particles. Those particles which passed through fell into a box, in which there was a constant upward current of water with a velocity of about one foot per minute. The finer grains were thereby brought in suspension to the top of the box, where they were weired off with the water, while the sand remaining in the box was drawn off during the process of washing, and stored for use in the filters.

The river sand had an effective size of from 0.23 to 0.27 mm., with a uniformity coefficient 1.8 to 2.0. The finished filter sand had an effective size of 0.34 mm., with a uniformity coefficient of 1.6. The water used for washing was drawn from the settling reservoir through a temporary line of 8-inch pipe. The total cost of labor, lumber, screens, tools, and other incidentals for grading both sand and gravel was $5,966.19, which, added to the cost of the sand and gravel, brought the cost of the same to $14,448.86, or $3.10 per cubic yard.

After the contracts for the filters and material had been awarded and the work was well under way, notice was filed by Mr. Ira H. Jewell through his attorney that the plans for the filters contained infringements upon patents issued to him, and that he would demand the sum of $35,000.00 as compensation for the use of any of his inventions. After a considerable number of conferences it was decided that as there was a question whether some of the features of the filter plant as independently developed by local experimentation might not embody improvements covered by letters patent issued to Ira H. Jewell, although no reference to any such patents was had while designing the filter plant, and as legal proceedings, if instituted, would result in protracted and vexatious litigation and expense, and might cause considerable delay in the completion of the filter plant, and as Mr. Jewell had finally agreed to accept the sum of $15,000.00 in full compensation for the right of the city to use any and all improvements relating to the purification and filtration of water covered by letters patent, issued or to be issued, to Ira H. Jewell, excepting one covering the cleansing of filter beds by an overhead mechanism, that a settlement on that basis be made. On July 11, 1906, an agreement was drawn up and executed in accordance with the conclusions and the report of a special committee of the Board, which were in substance as above stated, and covered the following letters patent: No. 646,837, No. 649,410, No. 664,088, No. 649,409, No. 649,411, No. 671,023. No changes or additions, however, were made in the design of the filter plant because of the acquisition of these rights.

On October 4, 1905, a communication was received from the New York Continental Jewell Filtration Co. and from Mr. O. H. Jewell, giving notice that they were the own-

ers of certain letters patent covering the application and use of a partial vacuum in filtering water through a sand bed or filter. A suit having been brought in the U. S. Court for the Western District of Pennsylvania to determine the rights of these parties under the letters patent held by them, nothing was done regarding these claims until after December 8, 1906, when notice was received that, after all the evidence had been submitted by both sides at interest in the above suit, an agreement had been arrived at between them, resulting in an amicable settlement, which was to include a like settlement with the City of Cincinnati, as it had been of great assistance to the defendants in the case. The matter was referred to the legal clerk, who, after a conference with all parties at Pittsburg, recommended that the city obtain a license to employ the inventions covered by the letters patent referred to and to settle all claims with said parties for infringement for the sum of $2,500.00. The recommendation was adopted, and on February 1, 1907, an agreement and license was duly executed relieving the city from any further litigation regarding these claims.

In preparing plans and specifications for the various buildings of the Filtration Plant, such as the Head, Chemical, and Filter Houses, the shaft houses and those over the several valve chambers, particular attention was not only paid to their special adaptability and arrangement for the service required, but also to their producing a general pleasing effect in the surrounding landscape. With that end in view, Mr. G. Drach, architect, submitted a number of sketches along indicated lines, which resulted in his preparing the plans and specifications for these buildings. To these were added the plans and specifications for a concrete wash-water reservoir, a chimney, laying of mains, and other work incidental to the completion of the Filter Plant, excepting the operating machinery and other apparatus.

On May 8, 1906, only two bids were received for this work, though it was very widely advertised. The bids in the aggregate amounted to $273,002.00 and $274,894.75, and were submitted respectively by the L. Eid Concrete Steel Company and L. P. Hazen & Co., both of Cincinnati. The contract was awarded to the L. Eid Concrete Steel Co. The work included, in addition to the Head, Filter, and Chemical Houses, two shaft houses, houses over seven valve chambers, a wash-water reservoir and chimney; also all necessary grading, draining, plumbing, piping, electric lighting and wiring and other miscellaneous work, various parts of which were to be completed by December 15, 1906, and all of it to be finished by December 1, 1907. The beginning of much of the work depended upon the progress made by the contractors constructing the filters and valve chambers.

Preparatory work was commenced early in July. The excavation for the wash-water reservoir was the first work started, the concreting of which commenced August 1, and although work was simultaneously started on the Head House, Chemical House, and pipe laying, it was not pushed with great energy, largely for want of men, until in September, after which time fair progress was made, and the work crowded as late into the winter season as it was safe to proceed. The erection of the valve and shaft houses, the Head House, and the Chemical House, with its concrete saturator tanks, stirring tanks, piping, chimney, and other work, was pushed with a great deal of energy. The failure of the filter contractors to complete the filters in time greatly delayed the erection of the Filter House, thereby retarding the installation of the electrical controlling panels, the operating tables, the electric wiring, and other work, so that it became necessary to almost crowd them off the work. Concrete work on the south half of the Filter House was started during the last week in July, and this part was sufficiently enclosed by September to permit of the operating machinery being placed, as well as the valve motors and switchboards, every effort being made to bring the work, where at least part of the filters could be placed in service.

By dint of constant pressure on the several contractors, the work was brought to that condition which permitted a few of the filters being operated for short periods early in October, allowing the apparatus in the Chemical House, the controllers, valves in the Filter and Head Houses to be properly adjusted. On October 22 continuous filtering was commenced, and since November 1, 1907, all of the water supplied to the city has been filtered.

On July 26, 1907, a supplementary agreement was entered into with the contractors whereby they furnished and placed additional steel rods in the top of all roof beams and girders of the Head, Filter, and Chemical Houses to re-enforce the same against shrinkage strains, the same to conform to the specifications, at 2¾ cents per pound in the work.

On December 18, 1906, the time for completing the Head House and Valve Houses B, D, E, and F was extended to February 1, 1907; of the Chemical House to March 1, 1907, and of the south half of the Filter House to June 1, 1907. On May 31 the time for the latter was extended to August 1, 1907. The roof covering on the Filter House was delayed by a long strike of the roofer's men until about the middle of December, when this work was resumed and completed by January 15, 1908.

All of the work under this contract was completed by February 4, 1908. A final estimate of the work was submitted on March 14, 1908, in the amount of $271,674.20. Five per cent of this amount was, under the provision of the contract, retained as a guar-

antee that the contractors would keep all their work in perfect repair for the period of one year after its completion, in so far as such was made necessary on account of defective material and workmanship.

Some repairs to the roof, where it leaked, and to the bearing of the concrete roof girders where these rested upon some of the concrete columns became necessary, and were made by the contractors in a satisfactory manner.

The contractors for this work claimed damages for delay caused them by the work of other contractors, but when this was offset by claims on the part of the city, it was mutually agreed to withdraw all claims for damages and close the contract by the payment of the amount due on the work. Final payment of the retained five per cent was made on April 13, 1909. The total cost of the work under this contract was $271,674.20.

In connection with the Filter Plant, plans and specifications were prepared for furnishing and placing certain operating machinery and apparatus, which consisted of one 36-inch venturi meter for the wash-water line, two 60-inch venturi meters for the raw water lines, 28 filter rate, 12 pressure, and 4 saturator rate controllers, six sets of stirring machinery for slaking tanks, five for coagulant tanks, and four for saturators, four electric gauges, indicating and recording the elevation of the water in the coagulation and clear water basins, also loss of head gauges and sampling apparatus for each of the twenty-eight filters, a two tons refrigerating apparatus, and other appurtenances. The plans and specifications also provided for furnishing four sets of swinging elbows and floats for the floating tubes of the two settling reservoirs heretofore referred to.

The designs for the twenty-eight filter and four saturator controllers were the result of an effort to produce an automatic rate controller, which would be accurate, reliable, and positive in its operation. To Mr. Simon Vivian, the mechanical draughtsman, is the credit principally due for the conception of this rate controller. A ten-inch rate controller was built and tested, and after several modifications developed during the tests, its design was adopted for this work. The controller consists of a double disc balanced valve, operated by hydraulic pressure obtained from an independent source. The proper application of this hydraulic power is obtained through the medium of an auxiliary valve containing a diaphragm, which is moved by the changes in difference of pressure of water on the two sides of an orifice in the effluent pipe. This controller has been patented for the benefit of the widow of Mr. Vivian, who lost his life while testing the coal-hoisting machinery at the River Pumping Station.

On September 28, 1906, eight bids were received for this work, only two of which covered every one of the fifteen items, the aggregate amount of which were $68,077.00 and $85,277.00. One other bid covered all but two items, and aggregated $73,970.00, while the fourth bid covered all but four items, and aggregated $55,831.00. The other four bids covered but one or two items.

The Norwood Engineering Co., of Florence, Mass., being the only firm among the bidders which was engaged in the manufacture of filter operating machinery and apparatus, and their proposal covering every item, and they being the lowest bidder on most of the items, the contract for all of the work was on October 2, 1906, awarded to them at their aggregate bid of $68,077.00. This proposal included in connection with the furnishing of the two 60-inch venturi meters some large piping which was being furnished by the U. S. Cast Iron Pipe and Foundry Co. under their contract. By eliminating this from their proposal, the Norwood Engineering Co. agreed to a reduction of $1,850.00, making the total contract price $66,227.00. The delivery and placing of the machinery under this contract was timed so as to have the same proceed in accord with the progress of the other work on the filter plant, all of the same to be in place by July 1, 1907.

The failure of completing the filters and buildings within the specified time delayed the installation of much of this machinery, and the time for completing this work was extended to November 1, 1907. All of the machinery, excepting the refrigerating apparatus which was being furnished by a sub-contractor, was promptly delivered and placed as rapidly as the conditions permitted, and all of it, excepting the ice machine, was installed by November 1, 1907. Not only was there considerable delay, but a great deal of trouble was also experienced in operating the refrigerator satisfactorily, and many changes and alterations had to be made, the cost of which was charged up against the Norwood Engineering Co. This fact delayed the final payment under this contract until July 17, 1908. The cost of the machinery for the Filter Plant amounted to $57,219.00, the swinging elbows and floats for the floating tubes of the settling reservoirs amounting to $9,008.00.

On April 27, 1906, four bids were received for furnishing and installing two electric motor-driven centrifugal wash water pumps, each having a capacity of delivering 2,500 gallons per minute against a head of 60 feet, to be used to keep the wash water reservoir filled and for washing the sand in the filters. The bids varied from $4,790.00 to $8,500.00, and the guaranteed efficiency ran from 58.2 per cent to 64.0 per cent. The best proposition was that of Dravo, Doyle & Co., of Pittsburg, whose bid was the second lowest, being $5,235.00, with a guaranteed efficiency of 63.2 per cent. The contract was on May 1 awarded to this firm.

The pumps consist of DeLaval, motor driven, centrifugal pumps, the impellers being of hard bronze. The pump case is divided horizontally through the center, permitting the inspection of the pump without disturbing either piping. The motors are 66 H. P. Crocker-Wheeler make, and operate at 950 revolutions per minute. These pumps were to be installed by January 1, 1907, but the work was delayed by the tardiness of other contractors. They were, however, erected in the pump room in the basement of the Head House, and have been in regular service since October, 1907. On November 4, 1907, they were subjected to the specified capacity and efficiency test, and met every requirement. They were accepted, and final payment was made on January 14, 1908.

On April 27, 1906, four bids were received for furnishing and installing two electric driven centrifugal flushing pumps, each of a capacity sufficient to deliver 1,000 gallons per minute against a head of 240 feet. These pumps supply through the ten and eight-inch mains laid around the two settling reservoirs and the coagulation basins, the water and pressure for a number of 1¼-inch hose streams for periodically washing out the accumulated mud. The bids varied from $5,950.00 to $11,500.00. The contract was awarded to Dravo, Doyle & Co., of Pittsburg, who were the lowest bidders. They furnished two electric motor driven, four stage DeLaval turbine pumps, the impellers of which are hard bronze and hydraulically balanced. The pumps are direct connected to the motors by a flexible coupling. The motors are of the Crocker-Wheeler semi-enclosed type, of 110 H. P., and operate at 950 revolutions per minute. The pumps were to be installed by January 1, 1907, in the house over the distributing chamber at the weir, but the tardiness in erecting this building under another contract, delayed the same until in November. The pumps were installed before the close of the year, and a final estimate, less 10 per cent, allowed in January, 1908. A test of the capacity and efficiency of the pumps was made on November 23, 1908, and found to comply with all contract requirements. Final payment was made on December 22, 1908.

On May 7, 1907, one bid was received for completing valve chambers Nos. 1 and 3, located on the two lines of 60-inch pump mains, and two bids for placing a concrete floor 12 inches thick over the entire bottom of the pump pit, with the exception of the space occupied by the bed plates, counterweight and other pump parts. These bids were respectively $1,900.00 and $2,948.00 for the concrete floor. The contract was awarded to J. E. Gomien and C. W. Settle, of Madisonville, Ohio, who were the lowest bidders. The work provided for thorough drainage of all water from whatever source to the sump, and affords a dry, smooth, hard floor in the pump pit easily kept clean. The work was done carefully and promptly and while the machinery was in operation. The work was accepted on July 10, and payment made on July 23, 1907.

The L. Eid Concrete Steel Co. being the only bidder for completing the valve chambers, the contract was awarded to that firm at their bid of $2,023.00. This work consisted of providing operating platforms, installing the motors for operating the 60-inch gate valves, and the electric lighting and of roofing the chambers with brick arches supported on steel I-beams and covered with concrete.

This work was completed by the middle of October, and paid for on November 29, 1907.

On August 27, 1907, four bids were received for laying 3,575 feet of 8-inch cast-iron water main from the Filter Plant along the levee to the boiler house at the River Pumping Station, for the purpose of furnishing filtered water for the boilers and lavatories at this station. The bids varied from $1,983.25 to $4,546.85. The contract was awarded to Frank Burns, of Cincinnati, who was the lowest bidder. The pipes and valves were furnished from stock on hand, and the work of laying was prosecuted with energy. A number of sprinkling hydrants were connected and set along the levee for sprinkling service. The work was completed on October 26, 1907, and the final estimate in the amount of $2,020.26 was allowed on November 15, 1907.

On August 27, 1907, but one bid was received for constructing narrow gauge railway tracks, including the necessary grading at the River Pumping Station. The bid of $12,144.00 was considered too high, and the work was readvertised under modified plans and specifications which divided the work into several items — one for furnishing material and constructing the tracks complete, another for furnishing and delivering track material only, and a third for doing the necessary grading of the roadbed, furnishing all wood ties, and for laying the track material.

These items covered material and work for 3,800 feet of track on wood ties, 2,140 feet of sectional track on steel ties at California, with three standard gauge track crossings, switches, and other work, and also for furnishing 350 feet of sectional track on steel ties for the Main Pumping Station.

On October 29, 1907, four bids were received for furnishing all material and doing all work, which varied from $9,977.00 to $15,225.00. Four bids were also received for furnishing and delivering the track material only, which varied from $3,476.95 to $6,133.50, while two bids were received for doing the grading and laying of the track, which were respectively $5,000.75 and $8,973.25. The aggregate of the lowest bids for items 2 and 3 being lower than the lowest bid for item No. 1, the contract for the track material was awarded to the Cincinnati Frog and Switch Company, and for the grading, laying of tracks, and other work to Chas. Underhill, of Cincinnati, each of whom were the respective lowest bidders.

The sectional track on steel ties was laid from the ends of the track in the boiler house to and in under the six lines of coal hoppers of the coal storage house. The other track leads from the boiler house to the standard gauge track on the levee, and is laid directly on the ties of that track for a distance of about 1,650 feet, where it leaves said track, diverging into two tracks, one leading to the site of the ash pit and the other leading to the Chemical House, forming a loop by connecting with the ends of the track in the boiler room.

The track material was promptly delivered, and the work of preparing the roadbed and of placing the several crossings proceeded without much difficulty or interference with traffic on the standard gauge tracks. The entire work was completed by January 16, 1908. Final estimates were approved on January 24, five per cent being retained until early spring, when the balance was paid, the contract for the material amounting to $3,582.32 and for the laying to $5,112.72.

On May 7, 1907, five bids were received for furnishing and delivering a narrow gauge locomotive at the River Pumping Station for hauling coal and ash cars. The specifications allowed bids to be submitted for steam, gasoline, and electric storage battery locomotives. But one proposal was received for a steam locomotive, which was $2,095.00. The bid for the gasoline locomotive was $2,250.00, while three bids for the electric storage battery were respectively $2,280.00, $3,000.00, and $5,337.00. Having facilities for charging electric storage batteries, and there being many advantages in the use of electric power over that of steam for the service required, the contract was awarded to the Westinghouse Electric & Mfg. Co., of Pittsburg, they being the lowest bidder. The contract included furnishing a charging tablet and all necessary instruments, the locomotive to have a capacity of hauling nine tons at a speed of four miles per hour and of performing a specified amount of work per day. The locomotive was delivered during the latter part of September, but not tested until January 20, when it was found to comply with all requirements. Final payment was made on January 24, 1908.

On May 7, 1907, six bids were received for furnishing and delivering twenty-seven coal cars and eight ash cars, which bids varied from $2,475.00 to $7,197.00. The contract was awarded to Arthur Koppel Co., of Chicago, that firm being the lowest bidder. Twelve of the coal cars, having a capacity of 40 cubic feet each, are boiler room charging cars, arranged so that both sides can be let down, and together with six tip cars for hauling ashes were to be delivered to the River Pumping Station, while ten coal cars of the same type and two ash cars were to be delivered for the Main Station and five coal dump cars were for the Western Hills Station. Some of these cars were

to be delivered in four weeks and the balance in ten weeks after the award of the contract. No attention was paid to this requirement, and the first delivery was not made until eight weeks, and the last not until six months after that time. The first cars were satisfactory, but the latter coal cars were evidently made in some other shop unfamiliar with that class of work. Most of these had to be gone over, and many rivets had to be cut out and the bottom re-riveted with countersunk heads. These repairs were made at the expense of the contractor, and amounted to $342.56. A change in the trap-door of the five dump cars was made by the contractor at an additional cost of $5.00 per car. On April 21, 1908, a final estimate was rendered to the contractor in the sum of $2,157.44.

THE GRAVITY CONDUIT.

During the earlier stage of the work it was contemplated that the gravity conduit conveying the filtered water from the clear-water basin to the Main or Western Pumping Station, located on Eastern Avenue, opposite the foot of Torrence Road should consist of a tunnel from the foot of the shaft at the clear-water basin to the northwest side of the Little Miami River, a distance of about 3,000 feet, and that from that point it should consist of a riveted steel shell, lined on the inside with a ring of concrete, or one ring of brick as a protection against corrosion. This scheme did not meet with undisputed approval. On January 19, 1900, test borings were started along the line of the proposed conduit with the view of constructing the same in tunnel through the rock formation from the proposed Main Pumping Station eastward. The advantages of a tunnel conduit over any kind of a conduit laid nearer the surface being so manifest, it was decided to construct the same in tunnel as far as the character of the rock formation would justify the same. The tunnel construction permitted the selection of as direct a line between the pumping station and the clear-water basin as the course of the river would permit, while surface construction compelled selecting a route above high water wherever such was possible, and necessitated a longer line, as well as increased the expense and difficulties of construction. The test borings were started at the site of the Main Pumping Station, and from there were continued eastward about one thousand feet apart. These borings were carried down to the bed rock, and then continued as 2½-inch core drills to elevation — 80.00. Each hole was sealed at elevation — 65.00 in order to determine the seepage of the rock between that elevation and the bottom of the boring. The first five borings gave such satisfactory results that it was determined to construct the west end of the conduit in tunnel. The bed-rock on the Main Station site was found at elevation +20.34, and at the fifth boring east

thereof at elevation — 50.33. These borings were found to be dry or else contained so little seepage that no difficulty in construction was anticipated.

Plans and specifications were prepared to let the west part of the conduit work in two sections, the first for a seven-feet diameter brick and concrete lined tunnel 2,400 feet in length from the outlet shaft in the rear of the Main Pumping Station eastward, the second section a continuance of the tunnel for an additional 4,700 feet, with one working shaft and an end shaft, should the borings continue favorable for that distance. A brief description of the tunnel has been given in the earlier part of this report.

On July 3, 1900, seven bids were received for constructing both sections of the tunnel, the bids in the aggregate varying from $308,164.80 to $463,135.40. The test borings by this time covered the entire length of the two sections, and indicated a continuance of the favorable condition of the rock for the tunnel work. The rock consisted of nearly horizontal layers of limestone and shale, and seemed to contain but little water. The contract for both sections was awarded to W. J. Gawne & Co., of Cleveland, Ohio, that firm being the lowest bidder, and included 7,100 feet of tunnel, the permanent outlet shaft, a working shaft about 4,900 feet east thereof, and a permanent shaft at the east end of the tunnel, intended to connect the tunnel with the surface conduit should that style of construction be found more desirable for the remainder of its length. The test borings were continued beyond the city limits to determine whether it would be practical to continue the tunnel construction beyond this point. All but three of the fifteen test borings, which were completed by August 13, 1900, indicated conditions very suitable for driving a tunnel. The three, which were over 5,000 feet apart, showed in each case the existence of considerable water in the rock at these points, the worst being at the location of the inlet shaft, yet this was not considered to be sufficient to prohibit the construction of the conduit for its entire length in tunnel. The plans and specifications for the balance of the tunnel were prepared and the work advertised. On October 2, 1900, four bids were received, which varied from $655,950.00 to $818,175.00. The lowest bid was that of Walton, Millett & Co., of Knoxville, Tenn., the next lowest bidder being The W. J. Gawne Company, whose proposal aggregated in the sum of $659,230.00. After a full consideration of the matter, the contract was awarded to the W. J. Gawne Company, which firm was then engaged in constructing the first section of the tunnel. The construction of the permanent shaft at the east end of the tunnel under the first contract was dispensed with. The second contract covered 15,164 feet of tunnel, two intermediate working shafts and the permanent inlet shaft at the clear-water basin. All working shafts were to be re-

moved, the openings in the arch closed with four rings of brick, and the shaft space above filled with concrete to a level with the rock surface, above which the shaft was filled to the surface with excavated material. All surplus material excavated from the tunnel and shafts was used in raising the grade of Kellogg Avenue and of the Columbia and New Richmond Turnpike, along which the shafts were located, to elevation 55.00. The material was spread in layers not over 6 inches thick and thoroughly rolled. The section of the tunnel crossing under the Little Miami River was re-enforced for a length of 1,000 feet by imbedding ¾-inch round steel hoops every two feet in the concrete lining outside of the brick lining, as this section has insufficient weight of material over the conduit to overcome the hydrostatic pressure in the conduit when in service.

Work on the first section was commenced in September by sinking the outlet shaft or shaft No. 1 and the first working shaft or shaft No. 2. The outlet shaft or shaft No. 1 went through 33 feet of clay and 102.7 feet of rock without the use of compressed air, and reached the tunnel level at elevation —78.75 by the end of December, 1900. Shaft No. 2 was sunk through 100.6 feet of loose material overlying the rock by excavating the material from within by a clam shell. When rock was reached at elevation —47.00, air pressure was used to force out the water, and the rock was excavated and the shaft lining carried down under compressed air. All the other working shafts were sunk in like manner.

On January 4, 1901, W. J. Gawne & Co. assigned their contract to The W. J. Gawne Company. On January 22, 1901, a supplementary agreement was entered into with the contractors, providing for the extension of the steel shell of shaft No. 1 from elevation 105.00 to elevation 140.00 at $85.00 per foot.

During the early stage of the work, while the tunnel excavation proceeded from both shafts, considerable number of complaints were made by the owners and occupants of buildings and by the Cincinnati Gas Company located over or along the line of the tunnel regarding the heavy charges of explosives used by the contractors. Investigation showed that no damages had yet been caused, but the contractors were directed to reduce the amount of dynamite used for each charge.

On April 23, 1901, work was suspended on this section of the work on account of high water (Plate 73), and was not resumed until May 11.

On July 5, 1901, when the tunnel excavation had reached a point about 480 feet from the outlet shaft, an explosion occurred which caused the death of four men, including the foreman and injuring a fifth man, besides wrecking the shaft elevator and the head house. On July 27 a second explosion took place at the same point, more or less seriously burning eight men, two of whom died from their injuries. Investigation of

the causes indicated the presence of natural gas escaping through the rock with the water leaking into the tunnel. As the hydrogen of this gas becomes highly explosive when mixed with air in any percentage ranging from 9 to 66, the contractors were at once advised of the condition, and directed to increase the supply of air to the heading sufficient to avoid endangering the lives of the men at work in the tunnel. This the contractors refused to do, contending that "the volume of air supplied by them is amply sufficient to keep the tunnel well ventilated under all ordinary conditions." Examinations of the air in the two headings from shaft No. 2 also showed the presence of explosive gases at these points. Work was not resumed at the first heading, and on August 31, 1901, the contractors suspended work at the other two headings also.

On September 24 and October 18 the contractors were formally notified to resume work at these points without further delay, failing in which the Board would cancel their rights in the contract and proceed to relet the unfinished part of said work. On October 30 official notice to that effect was again served upon the contractors and their sureties. No notice being taken thereof by either party, the Board on November 12 adopted resolutions annulling and cancelling all the rights of the contractors, holding them responsible for all loss and damage sustained by the city by reason of their neglect and refusal to proceed with the work, and ordered that specifications be prepared to relet the unfinished work. These, together with the form of contract were adopted on November 19 and the work advertised.

On December 24, 1901, two bids were received for completing this work, which bids in the aggregate amounted to $268,596.13 and $309,547.65. The unit prices of even the lowest bidder for the work were very considerably above the contract prices. In the meantime the Gawne Company contended that they had not abandoned their contract nor intended to do so, but awaited an adjustment based upon the extraordinary conditions encountered on said work, due to the presence of a highly explosive natural gas, which was not contemplated nor anticipated at the time of the letting, and that furthermore they would resist by all legal means any attempt to deprive them of their rights. On the day the bids were received the corporation counsel notified the Board that in pursuance to a former request of several taxpayers he would that day file suit enjoining the board from taking any action upon the bids received for the completion of the tunnel work. On January 17, 1902, the matter was referred to a special committee for thorough consideration. On January 24 the two bids were rejected and all resolutions regarding the cancellation of the contract and the reletting of the work were rescinded, and on the recommendation of the special committee, made after several conferences were had with the contractors, a supplementary agreement was entered into with the

contractors, which provided that in consideration of the extraordinary conditions which had arisen and of the contractors assuming the same and of completing shaft No. 1 and 500 feet in length of tunnel from said shaft and of turning said shaft and the site of the proposed Pumping Station over to the Board not later than May 1, 1902, the contractors were to be paid the sum of $9.50 per lineal foot of uncompleted tunnel in addition to the contract price. It further provided for the construction of an additional working shaft to be paid for at the contract price. Work under this contract was resumed on January 25, 1902, and continued without much interruption excepting during the months of February and March in 1903 on account of high water, and when the work under the property of the Cincinnati Gas & Electric Co. was suspended from May 18 to August 3, 1903, pending the conclusion of an agreement with said company as to the manner of driving said tunnel. While excavating under said property the maximum charges of explosives used were reduced from 36 to 18 pounds and later to 12 pounds. No damage was done to any property along and adjacent to the line of the tunnel, though a great many claims were filed and suits entered, some of which have been tried in the lower courts with a verdict in favor of the contractors. A sufficient bond given by the contractors protects the city against these claims.

In the heading from shaft No. 1 and in the west heading from shaft No. 2 a considerable quantity of water was encountered, and air pressure up to 40 pounds was used while lining these sections of the tunnel. These sections, amounting to about 350 feet in length, and the lining of the shafts were the only portions of the work which were finished under compressed air. These, however, were not the only wet sections of the entire tunnel. In some sections the water poured in under pressure from every part of the excavation, the rock in places being quite loose. When these sections were trimmed ready for lining with concrete and brick, the water was collected in pipes or in sheet-metal pans shaped to conform to the rock, and conducted to pipes which passed through the lining, thus giving the water ample opportunity to flow freely into the tunnel section, although confined to pipe outlets. This permitted the construction of the concrete and brick lining around these channels without washing out the cement or mortar. Some sections of the tunnel contained fully three hundred such pipe outlets in a length of one thousand feet, the pipes varying from one to two inches in diameter, and all discharging water freely. After the concrete and mortar had become hard and before the compressed-air pipes were removed, neat cement grout was injected into these drain pipes under air pressure varying from 60 to 80 pounds per square inch and until the flow of grout ceased. The grout under that pressure traveled through the pipes over and around the pans and into the fissures of the rock, stopping all leaks. In some instances

the grout would make its appearance in drain pipes fifty feet away. These sections of the tunnel proved later to be free even of moisture.

The work under the first contract, with the exception of the removing of the working shafts, was practically completed by December 1, 1903.

The work under the second contract progressed at a fair rate without other serious interruptions than those from high stage of river water, which surrounded the shafts, and occasionally from lack of brick and other construction material. The work was carried on from six headings, and these were connected at different times, the last connection being between shafts No. 2 and 3, which was made on October 29, 1903, when the entire tunnel was opened from the inlet to the outlet shaft. All of the work under both contracts, with the exception of cleaning up and leveling the grounds around the working shafts, was completed by May 17, 1904, when the final estimates were submitted and final payments, less five per cent were made. Under the contract five per cent was retained for one year to cover the cost of any repairs due to defective material or workmanship.

The time for the completion of the work under both contracts was extended several times, the last time until May 1, 1904. Final payment was made on May 12, 1905, the total cost of the work under both contracts amounting to $1,011,466.42.

As the grade of this gravity conduit is from 160.00 to 170.00 feet below the water in the clear-water basin, from which this conduit takes its supply, it was very desirable to know the amount of leakage, if any, that took place along the four and a-quarter miles of tunnel. As it was then impracticable to make a test under any head which would approximate the above condition, the first test was made as to the amount of leakage into the tunnel during average stage of river with an external head of 95 feet on the tunnel, by constructing a dam at the lower end of same with a section of pipe inserted about six inches below its top. After the flow through the pipe had become constant the same was measured at different times, and found to be about ten gallons per minute or nearly 15,000 gallons per day for the entire length of the tunnel. The tunnel was allowed to fill by infiltration, and observations made at different times, months apart, verified the result of the above test. Later, the tunnel being filled, the end shafts were filled to as high an elevation as was then possible, and very accurate observations made of the rate at which the water in the shafts fell. These tests were made a number of times, and the loss, while the tunnel was under a net head of 36 feet, was found to be near 14 gallons per minute. In order to determine the losses of water at various points a careful test was made recently after the tunnel had been in service for nearly two years, and the loss was found to be 103,680 gallons per day, while the

tunnel was under a maximum net head of 82 feet, a condition which will compare most favorable with any other existing masonry or even pipe conduit of proximate diameter.

MAIN PUMPING STATION.

In September, 1897, it was determined that the most available location for the Main or Western Pumping Station was on Eastern Avenue, opposite Torrence Road, where the river afforded sufficient depth of water for a good coal landing and the grade of the street fronting the property is above the highest stages of water reached by the river, and where there is sufficient depth between the street and the river to accommodate the buildings required. In 1898 this property, having a front of 500 feet on Eastern Avenue, was acquired by condemnation proceedings. The land acquired amounted to 7.93 acres and cost $34,000.00.

In the spring of 1900 the Ohio River began to cut into the bank of this site, when it was deemed best to at once proceed with protecting the same. Plans and specifications were prepared for grading an embankment slope and of protecting the same with rip-rap and a stone-paved revetment. On April 10, 1900, three bids were received for this work aggregating from $9,607.50 to $12,948.00. The lowest bidder having previously defaulted on city work, his bid was excluded and the others being considered too high, they were rejected and the work readvertised. On May 15, 1900, three bids were again received, varying from $12,069.50 to $13,116.20, and these being all considered too high, they were all rejected and the work held in abeyance until later in the year, when the contract for the first section of the gravity tunnel and the outlet shaft located on this site, having been let, it was decided to deposit the rock excavation from the tunnel over the face of the river bank as a temporary protection.

The contract for the pumping machinery for this station having been awarded on July 17, 1901, and the size and form of the pump pit and buildings having thereby been determined, plans and specifications were prepared for raising the ground by filling, for the revetment of the slopes, for the construction of the pump pit and the archway connecting the pump pit with the outlet shaft of the gravity conduit, of the foundations for the engines and buildings, and other work in connection therewith.

The filling of the site to elevation 74.00 required about 80,000 cubic yards of material, to be brought in from some other location. For this purpose a lot on the hillside opposite the pumping station site, fronting 573 feet on the north side of Columbia Avenue and 240 feet deep, was purchased for the sum of $8,430.00. Previous to preparing these plans, five test borings were made to determine the elevation of the rock forma-

tion and the character of the overlying material under the pump pit. The rock was found to be at elevation 20.34 to 24.54 excepting at the west end, where the rock was found at elevation 34.78, with a decided dip to elevation 19.87.

On April 4, 1902, seven proposals were received for this work, the aggregate bids varying from $170,527.30 to $230,695.00. The contract was awarded to the Western Construction Company, of Indianapolis, Ind., who were the lowest bidder. Work of clearing and stripping the grounds was commenced within two weeks, while the regular equipment for carrying on the work was being brought on to the grounds. Aside from the grading and revetment work, the contract provided for the construction of a rectangular pump pit 266 feet in length by 66 feet in width at the bottom and 22 feet 2 inches in depth, the walls of which were to consist of Bedford oolitic limestone resting on a pile and concrete foundation. The walls are 8½ feet thick at the bottom and 4 feet at their top, the longitudinal walls, as far as they extend, forming the foundation for the walls of the main building. The inside faces of the walls, the coping, the beds and joints of all face and arch stones were to be fine-pointed. The concrete foundation for the front and end walls extends down to elevation 50.00, and for the rear walls to elevation 43.00, and extends to one foot below the top of three rows of white oak piles spaced two and four feet apart and driven down to the rock formation. Within the walls the foundation for each of the two groups of pumping engines, consisting of a block of concrete 118 feet long by 39 feet wide and 8 feet in depth, rest each at elevation 45.00 on 280 white oak piles driven down to the rock. The floor area of the pump pit between the engine foundations and the pump-pit walls, excepting along the rear wall, is covered with a bed of concrete 2 feet 9 inches in depth, finishing 3 inches below the top of the engine foundation. Between the rear wall and the engine foundations a pipe pit 9 feet wide and 9 feet deep, extending the full length of the pump pit, is floored with concrete between the engine and wall foundations, in the form of a circular invert. This pipe pit is connected by an archway 100 feet in length and 12 feet in diameter, passing through the center of the rear pump-pit wall, with the wall of a brick tower around the outlet shaft. The invert and sides of the archway are constructed of concrete, and the arch consists of four rings of brick. The tower wall is circular, leaving a space of three feet outside of the outlet shaft, and under this contract extended from elevation 40.75 to elevation 74.50. The foundations for the main building extending 41½ feet beyond each end of the pump-pit walls, and for the boiler house consists of concrete 4½ feet deep, and where they join the pump-pit walls are provided with grooved joints to allow for independent settlement of the walls. The contract also provided for 246 concrete piers for the support of the coal-shed columns, also for furnishing and

laying all drain and sewer pipe and for laying all cast-iron pipes, including the 84-inch diameter cast-iron supply pipe in the archway and the 72 and 60-inch supply mains in the pipe pit..

The work of excavating the pump pit was commenced in May and that of driving piles was started on July 1. On June 10 a steam excavator was set to work in the borrow pit on the north side of Columbia Avenue. It was not long before it developed that the material in the borrow pit consisted largely of a soapstone formation which required blasting to remove. On August 12, 1902, the contractors submitted a proposition that if the Board would secure a piece of property west of Lumber Street and south of Cushing Street, along the bank of the river, the same to be used as a borrow pit for this work instead of the borrow pit on Columbia Avenue, they would reduce their contract price of 37 cents per cubic yard of embankment to 32 cents for all the material taken therefrom. This proposition was accepted, the property fronting 545 feet feet on Cushing Street and running to low-water mark of the river was purchased for $10,000.00. The property on Columbia Avenue was sold back to its former owner for $5,620.00, and on September 9 a supplementary agreement was entered into with the contractor incorporating said proposition, and providing that the contractor will protect the city against all claims of damage, and restore the borrow pit on Columbia Avenue to a condition satisfactory to its former owner, and that they remove all unsuitable material in the new borrow pit at their own cost and expense.

On September 23 a supplementary agreement was entered into which provided for furnishing and driving a number of piles for the foundation for the front wing and vestibule of the main building at 40 cents per lineal foot of pile in place.

On November 18, 1902, a supplementary agreement was entered into, which provided, at an additional cost of $1.79 per barrel for the use of Puzzolana cement in the face joints of the stone work to avoid discoloration of the same. As the contractors experienced considerable difficulty in securing sufficient stone of such uniform quality and character as to meet the requirements of the specifications, they applied for permission to substitute Portland cement concrete of ¾-inch stone for the limestone specified in the walls of the pump pit from the pump-pit floor up to the under side of the coping. This permission was granted, and on March 31, 1903, incorporated in a supplementary agreement, with the provision that the dimensions and shape of the walls remain unchanged, that the walls be built in alternate sections with proper joints between, that the face of the walls present a true and smooth surface of uniform color and grain with false joints giving the same the appearance of stone masonry, all without additional expense to the city and in compliance with the special specifications which were made a

part of this agreement. After the delays caused by the change in the borrow pit and that of the material of the pump-pit walls, the work progressed at a fairly satisfactory rate. The material obtained from the new borrow pit was a very good quality of clay, and was rolled into a very solid and compact mass. The concrete walls also proved to be a very good substitute for the oolitic limestone, the faces presenting the appearance of first-class stone masonry. The time for the completion of this work was extended several times, finally to November 15, 1903. The work was completed on the following day, when a final estimate in the amount of $181,321.93 was returned and paid. The total cost of this work, including the cost of the borrow pits and of some minor additional work, amounted to $195,858.71. During the latter part of the summer of 1903 a crack in the archway between the outlet shaft and the pump pit indicated that a settling of the ground was taking place, which later observations on the building foundation and on the piers for the coal-storage buildings confirmed. Some auger borings made in the bottom of the pipe pit showed the presence of a soft, compressible blue clay immediately above the rock formation. Thereupon in September four test borings were made 50 and 100 feet apart to the rear of the outlet shaft, from which it was ascertained that this layer of soft, blue clay covered the rock to a depth of from 10 to 12 feet. The settling was evidently caused by the accumulated weight upon this compressible material. Careful periodical observations were continued to determine as far as it was possible the probable extent and character of the settling which was taking place.

Meanwhile, in connection with this work, bids were invited by advertisement for furnishing and delivering about 170 tons of straight pipe and 135 tons of special castings, each varying from 6 to 84 inches in diameter, and to be used and laid by the contractors building the pump pit and foundations. On March 14, 1902, but one proposal was received, which was accepted, it being that of the U. S. Cast Iron Pipe & Foundry Co., whose bid aggregated to the amount of $23,155.14. As the contractors who were to lay this pipe were somewhat behind with their work, and needed the entire site of the pumping station for their work, the contractors for the pipe stored the same in their yards at Addyston, Ohio, until they were needed at the work. The pipes and special castings were all delivered by early fall of 1903, and a final estimate and payment in the amount of $21,564.91 was made on November 4, 1903.

Mr. G. W. Drach, a leading architect of the city was engaged to prepare the plans and specifications for the main building and boiler house for this station. The present design was approved, and later, on December 22, 1902, the plans, specifications, and form of contract for the buildings and two chimneys were adopted and the work advertised, bids to be received for the walls of the main building to consist either of fine-

grained oolitic Bedford limestone, best quality of Berea sandstone or of steel concrete. A description of the buildings and chimneys has already been given.

On February 17, 1903, ten bids were received for this work, of which two were not in accordance with the specifications. Of the eight remaining bids four were for constructing the walls of the main building of limestone, and varied from $379,635.20 to $458,656.00, two for constructing same with sandstone, and were respectively $440,857.20 and $451,733.21, while the other two bids provided for constructing the main building of steel concrete, and amounted in the aggregate to $413,656.00 and $418,033.21. The contract was awarded to the U. S. Construction Co., of Milwaukee, Wis., who were the lowest bidders.

This company was then engaged in the erection of buildings for the River Pumping Station and in the construction of the settling reservoirs under an assignment of that contract, the progress on both of which was not very rapid.

The work of grading the site and of constructing the foundations for the several buildings of the Main Pumping Station had advanced sufficiently by September 1, 1903, to permit the U. S. Construction Co. to prepare for their work, and possession of the grounds was then tendered them. It was evident, however, that the contractors intended to delay until they could complete the buildings at the River Station, and then bring their force and equipment on to this work. The financial difficulty into which the company had drifted during the winter of 1903 on account of its utter inability to profitably handle the reservoir work, and which necessitated the creditors to finish the work at the River Station, caused the company to seek some way by which it might assign its contract for the buildings at the Main Station with some profit to itself. It finally succeeded on March 25, 1904, in securing the consent of the Board to assigning the contract to the Luenzmann Construction Co., of Milwaukee, Wis. The first preparation made by this company for carrying on the work was the erection of a high trestle, including a bridge spanning Eastern Avenue, for a side track from the Pennsylvania Railroad tracks north of the avenue to the site of the buildings, whereby all the heavy stone and other construction material could be delivered on the site by cars and without carting.

Work on the main building was begun on May 26, 1904, and pretty fair progress was made until in January, 1905, when the weather interfered therewith. The end walls of the main building showed that the ground was still settling under the additional weight of the walls. A grooved joint in the walls at the corners of the pump pit, which was concealed in the offset of the pilaster, allowed the walls to respond to the settling of the foundation without causing any cracking of the same. As it would be

impossible to conceal any crack in the brick walls of the boiler house, annex, and shaft tower, a change was made in the foundations for the boiler house and annex by driving clusters of five simplex concrete piles under each pilaster of the boiler house and annex down to the rock formation. These piles were 49 feet long and fitted with cast-iron points, which penetrated into the rock. Each cluster of piles was capped with a concrete block, which supported a solid steel concrete beam, which in turn spanned the 16 feet space between the clusters and supported the boiler-house walls. It was deemed inadvisable to drive a sufficient number of piles to support the two chimneys because of the effect which the necessary displacement of the solid clay might have upon the archway and other substructures located between the chimneys. The concrete foundation was therefore spread in each case to cover an area 40 feet square, with full-length one-inch corrugated steel bars imbedded each way into the lower 12-inch bed of concrete, the bars being laid 12 inches apart. This foundation was not expected to prevent settling, but rather to cause it to be uniform, and the flue connection to the boiler house was raised four inches at the chimney end to allow for that much settling. In connection with this change the height of the brick tower around the outlet shaft was lowered from elevation 146.00 to 96.3, so as to reduce the weight upon its foundation. These changes were provided for by supplementary agreements, under dates of March 3 and April 21, 1905, increasing the cost of the work by $16,470.00 less $4,093.00 on account of lowering the height of the tower. These measures have been successful in preventing any special damages to these structures.

This additional work caused some delay in the erection of the buildings, but fair progress was made after that. However, the beginning of the erection of the pumping machinery in February, 1906, interfered with completing some minor work, and arrangements were made by the contractors with the engine builders to complete this work when the progress of their work would permit. This arrangement was agreed to in order to hasten the contractors to clean up the premises and surrender the same, though the final estimate was not rendered until late in 1907. The time for completing the work under the contract was extended a number of times, finally to May 1, 1906. Much trouble, annoyance, and delay was had on account of the contractors subletting most of the work at prices not in accordance with the character of material and workmanship called for by the specifications, necessitating frequently the removal of material and work and of replacing the same with such as would conform to the specifications. This carried some of the work into 1907.

On July 23, 1906, the upper chimney was struck by lightning, and a considerable portion of the radial-faced pressed brick stripped off. The repairs were made by the

contractors at a cost of $612.50. A final estimate was prepared and paid on October 1, 1907. The total cost of all work done in connection with these buildings amounts to $393,442.20, of which $392,546.68 was paid under the contract.

The contracts for the coal-storage houses, hoisting machinery, and cars have been heretofore referred to.

Neither in the report of the Engineering Commission of 1896, nor in that of 1897, nor in the resolutions adopted by your Board on October 13, 1897, outlining the work to be undertaken in the improvement, enlargement, and extension of the Water Works of the city, was it contemplated to carry the work beyond the delivery of filtered water into Eden Park reservoirs. A further study of the existing conditions showed that by the installation of high-service pumping engines at the Main Pumping Station, with a suitable force main leading from there to the hilltops and a proper re-enforcement of the supply main into the different elevated districts, could not only a much better supply and pressure be maintained in the many districts which were suffering because of a scarcity of both, but that the pumping stations and service at Eden Park, Hunt Street, Linwood, and Cumminsville could be also dispensed with, and a very material saving in the cost of annual operation effected, as the additional number of men required to operate the additional pumping engines at the Main Station would not exceed five or six men per watch. Moreover, it would eliminate a re-pumping of the water delivered to the hilltops, as at this station it could be pumped direct from the gravity conduit. The advantages of concentrating all the pumping engines for the several services under one roof and in one room, were so manifest that the installation of high-service pumping engines with suitable boilers and of a suitable force main to the hilltops was added to the equipment which had been planned for this station.

In order to meet the additional expenditures caused by this addition to the original plans and to provide means for re-enforcing the distribution system as well as a general enlargement of the whole work beyond the lines as originally planned and to meet the increase in cost of the work due to higher prices of material and labor, the Legislature of the State of Ohio on April 25, 1902, passed an act supplementary to the original Water Works Act, authorizing the issue of additional bonds to the amount of $2,000,000.00, and again on April 22, 1904, an act authorizing the issue of bonds for an additional sum of $1,500,000.00.

Proceeding under the modified plans, the buildings and engine foundations were therefore all planned with the view of housing four units of low-service pumping engines of 25,000,000 gallons daily capacity each, and four units of high-service pumping engines each of 12,000,000 gallons daily capacity. Specifications were

prepared for high-duty, self-contained, vertical triple expansion crank and fly-wheel pumping engines of the above capacities and services, together with necessary boilers and other equipment of ample capacity to operate all the pumping engines and their appurtenances under conditions of maximum load.

On June 18, 1901, nine proposals were received from five bidders for furnishing and erecting three units of each size of pumping engine. These bids were as follows:

NAME OF BIDDER.	ADDRESS.	3 L. S. ENGINES & BOILERS.	3 H. S. ENGINES & BOILERS.	ELECTRIC CRANE.	AGGREGATE AMOUNT
Holly Mfg. Co.,	Lockport, N. Y.	$410,500.00	$391,900.00	$11,000.00	$813,400.00
Laidlaw-Dunn-Gordon Co.,	Cincinnati, O.	416,500.00	397,900.00	11,000.00	825,400.00
Allis-Chalmers Co.,	Milwaukee, Wis.	423,000.00	458,000.00	10,000.00	891,000.00
		453,000.00	458,000.00	10,000.00	921,000.00
		448,000.00	489,000.00	10,000.00	947,000.00
		478,000.00	489,000.00	10,000.00	977,000.00
Camden Iron Works,	Camden, N. J.	533,000.00	527,000.00	10,700.00	1,070,700.00
Kilby Manfg. Co.,	Cleveland, O.	587,500.00	593,500.00	7,000.00	1,188,000.00
		610,900.00	615,900.00	7,000.00	1,233,800.00

After a careful consideration of all the different propositions and details of the plans and specifications which accompanied each proposal, the contract was awarded to the Holly Mfg. Co., at their bid, with the understanding that without additional cost they agree to increase certain dimensions and weights, and also make some other minor modifications of their plans and specifications, all of which was agreed to and incorporated in a supplementary agreement under date of December 3, 1901. Under their bid they proposed to furnish either Babcock & Wilcox, Stirling, Peck, or Cahall horizontal water-tube boilers. On November 26, 1901, the contractors requested that the Geary water tube boiler be added to the list of boilers offered, which request was granted.

The first detail drawings were not submitted by the contractor until in December, and were mainly for the low-service engines. These were submitted in the form of two sets of blue prints, which were carefully examined and checked, one set being returned with such corrections or modifications as were found necessary or desirable, while the other was retained for reference. Thereupon the tracings embodying the changes were forwarded for approval; these after being compared, were dated and approved by the Board, and after three sets of prints had been taken, were returned to the contractor. One set of these prints were sent to the Inspector at the Works for his guidance. This method regarding plans was followed on all work of metal construction, and entailed an enormous amount of work in the office, not less than 1,188 sheets of tracings of shop

drawings submitted under different contracts being examined, checked, and approved. Five hundred and two such tracings were approved in connection with the contracts for the high and low-service pumping engines.

Aside from the anchor rods and plates, no work was done at the shops until October, 1902, when a few engine frames for the low-service pumps were cast, from which time on a very slow progress at the shops was maintained until October, 1905, although the contractors had been repeatedly urged to expedite the work on the high service pumping engines and boilers, as it was desired to put two of these pumps into service by May 1, 1906, in order to relieve the water famine conditions in the hilltops as soon as possible. Particular difficulty was had in getting the plans for the boilers and their foundations, and not until the monthly estimates in August and September, 1905, were suspended, was it possible to obtain any plans of that part of the work. Similar delay was experienced in the erection of the boilers and the auxiliary machinery in the boiler room, and especially so with the steam piping, the delivery and erection of which was not only slow, but in almost every respect very unsatisfactory.

The thirty-ton electric traveling crane which spans the building was delivered and erected in November, 1905. The contractors meanwhile secured from the building contractors the right to use the elevated railroad siding, and with it and the aid of an elevator, brought in all of the heavy castings and machinery by cars and within reach of the electric traveling crane in the building.

Erection of high service pumping engine No. 3 was commenced on February 27, 1906, and together with the erection of the other two high service pumps was pushed as rapidly as possible. The erection of the low service engines was commenced on May 12 in order to obtain more floor space, as the shipment of material was somewhat greater than the available storage room would accommodate.

The erection of the boilers and economizers was commenced on March 17 and was completed by September 19. After considerable vexatious delays, the erection of the steam piping was begun on September 3, but on account of delay in shipment, the progress was very slow. To hasten the delivery, much of the special steam piping was sent from Pittsburg by express at the expense of the city, so that the high service pumps might be placed in condition for service at the earliest moment, as the pumping machinery of the old works was constantly breaking down and apparently getting worse every day. The high service engines Nos. 2 and 3 had been completed for some time, but on account of delay in the steam piping, No. 3 did not do its first pumping until on October 6 and No. 2 on October 29. These pumps went into regular commis-

sion on January 2, 1907, and since January 20 have, in conjunction with No. 1, been alternately engaged in supplying all the water required in the elevated districts of the city east of Mill Creek.

The progress and erection of the low service pumping engines was very satisfactory; not so, however that of the steam piping for these engines, the same trouble being experienced as in the case of the other engines. Low service engine No. 1 commenced pumping on May 19, 1907; No. 3 on May 23, and No. 2 on June 1, and since June 16 these pumps have, with the exception of two days in July, furnished all the water used in the former intermediate service, and since September 25 also that used in the former low service, the division between these two services being at that time abolished.

The pumping machinery furnished under this contract has been running smoothly and very satisfactorily; not so, however, the boiler plant, which has required much repairing, the furnace walls of which had to be rebuilt by the contractors. This machinery, like that at the River Station was operated for some time by men employed by the contractors and under the supervision of their Superintendent of Erection, the city reimbursing the contractors for the wages of these men, plus ten per cent.

During the progress of the work several changes were made in some parts thereof which were covered by supplementary agreements under different dates. The agreement under date of November 10, 1905, provided for furnishing and erecting a checkered steel plate gallery with brass railing around all of the pumping engines at a level with the engine room floor, and of connecting same by stairways with the basement and also with the main engine house gallery, at an additional cost of $7,000.00. It provided also, at an additional cost of $1,140.00, for substituting two 34½-inch deep web plate girders and two lines of 60-pound rails as runways for the electric traveling crane in lieu of the 20-inch I-beams specified. It further provided for eliminating the flue connection between the boiler house and the stacks, and also the air duct in front of the boilers from this contract, for which it was agreed that the sum of $1,400.00 should be deducted from the contract price. Under date of March 30, 1906, an agreement was entered into which provided for finishing all exposed faces of the walls of the boiler settings, of the flue connections, the north walls and ends of the economizers, and the soffits of the flues and economizers with Cayuga light buff-colored pressed brick at an additional cost of $1,500.00. Under date of December 11, 1906, a supplementary agreement was made which stipulated that the contractors should furnish and place two 36-inch gate valves and two 24-inch gate valves on the openings of the suction headers and two 22-inch gate valves for the discharge header openings,

provided for connecting up the fourth engine in each service hereafter. For the valves delivered the sum of $1,986.00 was paid, while the contractor was reimbursed the cost of placing the same, plus 15 per cent.

Under the terms of the contract, each engine is subject to one year of probation, which commenced at the time the engine was put in regular service. During this year of probation a test trial of not less than 120 hours duration is to be made of the capacity and duty of each engine. Notwithstanding frequent requests to start with the tests, the contractors made no attempt to comply with this part of the contract until in July, 1908. It became quite evident from the very beginning, when the high service pumps were put into commission, that the entire boiler plant was not of ample capacity to operate all the pumping engines and their appurtenances economically under the conditions of maximum load, but that many parts of the entire installation, including the economizers, were more or less of an insufficient character, requiring more or less constant repairing. Moreover, the furnaces during operation did not prove to be of the smokeless type, as required by the specifications.

A test of the boiler capacity was made from November 6 to 14, 1907, of battery No. 3 of the high service boilers, from which it appeared that it required crowding the boilers to the utmost to comply with the contract guarantee and requirements.

The first test of any one of the pumping engines was made from noon July 28, to noon of August 2, 1908, when a 120-hour test trial was made of high service pumping engine No. 3 and its appendant battery of boilers, the data of which will be found in Appendix "G," as well as the records of all other tests which have been made of this plant.

The second test was made of low service engine No. 2 and its battery of boilers, commencing at noon of September 9 and continuing to noon of September 14. During this test the boilers were forced to even a greater extent than during the first test, and at a rate which would soon put these boilers out of commission. This was largely due to an effort to overcome the emission of smoke. The test of No. 2 high service pumping engine with its battery of boilers was made from September 25 to 30, and that of No. 2 low service pumping engine and boilers from October 19 to 24. As there was comparatively little difference between the duties developed by the two pumping engines of each service, it was mutually agreed that to save time and expense of further tests, that the duty of the third pumping engine in each service be accepted as an average of the two which were tested.

The data of all these tests may be found in Appendix "G."

The total cost of the work under this contract, which includes certain additional work and material furnished under Supplementary Agreements amounts to:	$821,640.00
For furnishing and setting additional gate valves and blank flanges	2,330.25
For extra labor cutting openings in walls	530.70
For services of engineer during the period of probation of the several engines, as per contract	4,500.00
For bonus earned under the contract during the several test trials	76,718.27
Total	$905,719.22

The contractors claim that they are entitled to a bonus of $107,506.98, based on picking slate out of the coal and on allowance of coal used for a proportionate amount of steam required to operate the fan engines, in face of the specifications that "nut and slack Pittsburg coal" shall be used, and that "all coal put into the furnaces during the test will be charged to the engine without any deduction of whatever kind except moisture." The contractors filed a claim for $29,282.40, being six per cent interest for three years on the twenty per cent of the contract amount which was retained under the terms of the contract until the entire work was completed. They also filed a claim for $19,351.25, being six per cent interest for three years on the alleged bonus of $107,506.98, also for $6,037.10, being the premiums paid by them on the surety bond since July, 1904, and for interest on these and other amounts, which claims aggregate in the sum of $89,127.06 above the amount of $905,719.22.*

These claims have not yet been adjusted nor has the total amount under the contract been paid, as the pumping engines have not yet been painted, nor have all the defective parts of the installation in the boiler room, principally around the steam pipe lines and valves and around the boilers been replaced, which the contractors during last November agreed to make good, which, however, at the time did not include making any further special provisions for the elimination of smoke except in an experimental way. The dilatory ways of the contractors leaves it uncertain when this work will be completed to comply with the contract and specifications.

On April 27, 1906, among a number of bids received for other material, but one bid was received for furnishing and erecting two 75 K. W. electric generators at the Main Pumping Station. This bid was submitted by Dravo, Doyle & Co., and proposed to furnish four Crocker-Wheeler generators driven by two De Laval steam turbines, each unit consisting of two 40 K. W. four-pole generators and operating at a speed of 1,200 revolutions per minute. The price paid was $8,650.00, and included all necessary steam and exhaust piping, the latter to connect also with the exhaust piping of the condensers of the high service pumping engines. The price also included all necessary instruments on the switchboard and all wiring thereto. The contract was awarded to Dravo, Doyle & Co. on May 1.

*NOTE. These claims have since been finally adjusted and settled by the payment of an additional sum of $17,812.70.

The generators were delivered in September, but as the contractors for the pumping machinery were occupying the entire floor space of the pump pit in the erection of the pumping engines, the installation of the generators was delayed until the following spring, since which time they have been in service, furnishing light to the buildings and grounds and current for the electric traveling crane. These generators also furnish the power for operating the various machine tools recently installed in the machine room of this station. The generators were subjected to the several tests called for in the specifications, and were found to comply with all the requirements. The final estimate was submitted, approved, and paid on January 14, 1908.

On November 2, 1906, five bids were received for furnishing and installing all circuits, conduits, boxes, switches, and lamps for lighting the pumping engines, boilers, hoist house, and coal storage houses at the Main Pumping Station. These bids varied from $1,180.00 to $3,145.00 The contract was awarded to A. S. Schulman, of Cincinnati, Ohio, who was the lowest bidder. Work was immediately commenced, and progressed very satisfactorily, excepting that the unfinished erection of the pumping engines delayed the wiring and lighting of these until after all of that work had been completed. It was under a supplementary agreement to this contract that the contractor furnished and laid a lead-covered, armored power cable and a lead-covered telephone cable through the intake tunnel from the River Station to the Intake Pier. On November 15, 1907, a final estimate was rendered, covering all the work under this contract to the amount of $3,213.50, on which an allowance of $940.95 was made for a lot of brass piping which was removed from the tunnel.

On March 22, 1904, specifications were submitted and approved for furnishing and laying the high service and low service pump mains from the Main Pumping Station, the former to consist either of a riveted steel pipe 49 inches in diameter or of a cast-iron main 48 inches in diameter, while the latter main was to consist either of a 61-inch diameter riveted steel pipe or of a 60-inch cast-iron pipe, both including necessary gate valves on these mains and on the branches thereof.

On April 29, 1904, several bids were received for each class of work. Two bids were received for furnishing and laying complete 13,200 feet of 61-inch and 3,265 feet of 49-inch riveted steel pipe, which were as follows:

Name of Bidder.	Address.	Aggregate Amount
The T. A. Gillespie Co.	Pittsburgh, Pa.	$554,636.00
Chicago Bridge & Iron Works	Chicago, Ill.	774,635.00

On the same day but one bid was received for furnishing and delivering the 60-inch, 48-inch, 42-inch, and other sized cast-iron pipe and special castings, which bid in the aggregate amounted to $347,580.40, and was submitted by the U. S. Cast Iron Pipe and Foundry Co. At the same time three bids were received for laying 13,200 feet of 60-inch, 3,265 feet of 48-inch, 3,330 feet of 42-inch, and 1,920 feet of 36-inch cast-iron pipe, specials and gate valves, which were as follows:

Name of Bidder.	Address.	Aggregate Amount.
The T. A. Gillespie Co.	Pittsburgh, Pa.	$366,278.75
F. H. Kirchner	Cincinnati, O.	379,882.00
J. W. Sullivan	Cincinnati, O.	445,682.50

All three sets of bids were considered too high, and were rejected, and the further consideration of these mains was postponed until February, 1905, when new specifications were prepared, calling for the use of a higher grade of cast iron, which permitted a reduction in the thickness of this large pipe and a consequent reduction of from 10 to 12 per cent in the tonnage, without any diminution in the strength. The location of the 48-inch high service pump main was also changed to follow Humboldt Avenue instead of along Torrence Road, whereby a safer route and a 25 per cent shorter line was secured.

On March 17, 1905, but one bid was received for furnishing and delivering the 48 and 60-inch cast-iron pipe and special castings required for the two pump mains which in the aggregate amounted to $272,204.00, and was submitted by the U. S. Cast Iron Pipe & Foundry Co. The contract was awarded to this Company on March 21. The casting and delivery of the 48-inch pipe was commenced in December, 1905, and continued with more or less regularity until the following December. This pipe was delivered as rapidly as it was cast and inspected at the foundry, and was distributed along the line of Humboldt and Columbia Avenues as fast as it was received. The casting of the 60-inch pipe was commenced in February, 1906, but the pipe was temporarily stored at the foundry at Addyston, Ohio.

The contract called for the delivery of the 60 and some of the 48-inch pipe either at the Pendleton Shops Yard or the Front Street Yard of the Pennsylvania Railroad. This company refused to receive the pipe, claiming that congestion at these yards prevented them from handling same. Following this refusal, an agreement was made with the pipe contractors whereby they were to allow the city sixty cents per ton for all pipe delivered at the Wood Street Yard of the B. & O. S.-W. Railway Co., in the west-

ern part of the city, which eliminated the transfer of the cars to the Pennsylvania Railroad Company. As the travel on Eastern Avenue, along which the 60-inch main was laid, is very great, it was impractical to store this pipe along the street previous to or during the time the same was being laid, hence arrangements were made to deliver this pipe in such manner and at such time that it could be lowered into the trench without delay. To facilitate this method of delivery, two vacant lots near the Wood Street Yards were leased for nine months at a rental of $30.00 per month, on which to store 60-inch pipes and specials received daily in excess of the number of pieces laid, or from which to supplement such delivery. All of the 60-inch and some of the 48-inch pipes were delivered in this manner, all of which was completed by March, 1907. The final estimate and payment on the pipe contract was delayed on account of some differences in the invoices, until January 24, 1908, the total amount paid under the contract for the pipe furnished for these pump mains being $259,399.20.

On July 28, 1905, bids were invited for unloading and hauling cast-iron pipes, special castings, and valves from various railroad yards and distributing the same along different streets. On August 29 but one bid was received for this work, which included hauling and delivering the 48-inch pipe for the high service pump mains at $1.75 per ton. The contract was awarded to George Reichel, of Cincinnati, at this price. This work was promptly attended to and done in a very satisfactory manner, the same being completed by July, 1906, at a total cost of $5,123.63.

On March 27, 1906, again but one bid, being that of George Reichel, was received for unloading, hauling, and delivering all of the 60-inch cast-iron pipes, special castings, and valves from the cars in the Pennsylvania Yards and from the Wood Street Yard of the B. & O. S.-W. Railway Company. As his bid for hauling the pipe from the latter yard was $2.00 per ton, or but fifty cents per ton more than hauling from the Pennsylvania Yards, the contract was awarded to him on that bid, which was ten cents less than the allowance made by the pipe contractor for delivery at that yard. The specifications called for a delivery either from the cars or the lots where they were stored to the streets at a rate and in the order in which the contractor for laying the pipes would each day require. The skillful compliance with these requirements aided very much in preventing serious interference with the congested travel on Eastern Avenue. The contract was completed and final payment was made on August 2, 1907, the total amount being $15,827.29.

On November 10, 1905, four bids were received for laying the 48-inch high service pump mains from the Main Pumping Station along Eastern Avenue to and along the strip of land secured for that purpose from Eastern to Columbia Avenue, and along

Columbia and Humboldt Avenues to Woodburn Avenue, where it connects with 36-inch mains running both north and south from this point. The length of this main is 6,091 feet, and the bids, which included concrete and brick masonry for valve chambers and piers, as well as rock excavation and other incidental work, varied from $42,705.00 to $65,385.00. The contract was awarded to Keeling & Ridge Co., of Pittsburg, Pa., who were the lowest bidders.

Work was commenced on November 25, 1905, but no great progress was made, although the contractors pledged themselves to expedite this work as rapidly as good workmanship would permit, as this main was to be used in the first aid which the new Works was to give to the old Works in supplying water to the city. The only time during which this promise was in a measure redeemed was during the months of April and May, 1906, when they laid 2,694 feet of pipe, while it took all of the following four months to lay the balance of 1,632 feet, notwithstanding they were constantly urged to finish their work. Considerable unnecessary delay was had in connecting the main with the discharge header in the Pumping Station. The main was filled in October, and after being subjected to pressure, developed several leaks, caused by the cut end of a pipe near a 53-degree bend pulling. Recalking of the joint did not overcome the trouble, for at this time a deep trench for a main sewer was excavated parallel to the water main, leaving a wall of earth but three feet thick outside of the bend. This yielded and permitted the cut end of the pipe to pull out of its joint a distance of 3½ inches, necessitating the emptying and uncovering of the main, when it was found that the pipe for a distance of from 24 to 30 feet each side of the bend had moved. The lead joints in this length were all cut out, the pipe readjusted, the joints re-run and calked, and the pipe imbedded in concrete, re-enforced with steel rods fastened to circular bands around the pipe. A similar leak, due to the pulling of the 20-degree vertical bend, was treated in like manner, and no further leak has been noticed on this main, though it has been in service for over two years and part of it subject to a pressure of over 200 pounds.

The contractors caused a great deal of annoyance and trouble in not promptly restoring the disturbed street surface and crossings to their former condition. A final estimate in the sum of $42,804.23 was prepared and paid on January 25, 1907, less ten per cent, which, in compliance with the specifications, was retained to guarantee the proper maintenance and repair of the work and street surfaces for a period of six months after the pipe line had been put under pressure. On July 23, 1907, the retained percentage was paid to the Mercantile Trust Company, of Pittsburg, Pa., assignees of Keeling & Ridge Co., after the street surfaces had been fully restored to the satisfaction of the Chief Engineer of the Board of Public Service.

In order to expedite the laying of the 60-inch pump main along Eastern Avenue, from the Main Pumping Station to a connection with the main leading to Eden Park Reservoirs and to the city at the intersection of Third and Martin Streets, a distance of 11,969 feet, plans and specifications were prepared for doing this and other miscellaneous work in connection therewith, under two separate contracts.

The first section, for which, on March 23, 1906, seven bids were received, covered a length of 6,643 feet, and extended from the Main Pumping Station to Broad Street. The bids in the aggregate varied from $60,399.50 to $76,309.75. The contract was awarded to the Kirchner Construction Co., who were the lowest bidders.

On the same day seven bids were also received for the second or lower section of this pump main, the lowest bid being that of A. M. Bowman, of Pittsburg, Pa., whose proposal was $27,483.00, while the other six bids were from $56,400.00 to $71,025.00. The lowest bidder declined to enter into any contract, and after having failed to sign the same within the required time, it was, on April 24, 1906, awarded to the Kirchner Construction Co., who were the next lowest bidders.

Proceedings were instituted, and are still pending against A. W. Bowman and his surety for the amount of the bond which accompanied the bid as a guarantee that the bidder would enter into contract if the work be awarded him.

Work on both contracts was commenced in May, and was pushed energetically, and with as little possible interference with public travel and convenience as the existing conditions would permit. The laying of this large main along the only thoroughfare leading from the East End into the city, with its double street-car tracks, its heavy and continuous travel, its railway crossings and numerous sewer, water, gas mains, and electric conduits and services occupying the area under the street surface, presented more and greater difficulties than any or all other sections of pipe lines which have been laid under the authority of your Board.

On the line of the second section of this main the 30-inch gas main from Kemper Lane to Third Street was found to veer from its supposed position near the curb over towards the street railway tracks to such an extent that the pump main was crowded to a location which necessitated the removal of the north track. The work of removing and relaying this track was paid for under certain paragraphs of the contract which provided that the contractor shall be reimbursed at cost, plus 15 per cent, of work which developed as necessary, but could not be particularized in the specifications. On May 10, 1907, a supplementary agreement was entered into, according to which the contractor was to be paid 90 cents per square yard for taking up and

relaying any additional width of granite block pavement over and above that required to lay the 60-inch main, and $5.00 per cubic yard of natural cement concrete used in foundation for such additional pavement. This became necessary on account of taking up the entire north track, including the ties.

Some delay was met with on account of the suspension of the work in the proposed relocation of Eastern Avenue at the Litherbury Crossing of the Pennsylvania Railway Company's tracks, which provided for diverting and depressing said avenue sufficient to carry the same under the tracks, in which case the 60-inch main was to be laid along the new line of street, and thus escape crossing under the series of tracks. No effort being made to solve the legal tangle, the main was laid along the present line of the street and at a depth of over 20 feet where it crosses under the railway tracks, in anticipation of avoiding any disturbance of the main whenever the railway company should bridge the street. Should the proposed improvement of this crossing ever be made it will leave a considerable length of main off from the street and under the railroad tracks.

The main, under both contracts, was completed so as to allow the same to be filled on April 23, 1907. Connections at Third and Martin Streets were made with the 36 and the 46-inch mains, both leading to the Eden Park Reservoirs and to the distribution system of the business section of the city, also with two lines of 24-inch mains leading to the old low service district. The old mains all served as pump mains, delivering water from the old Front Street Pumping Station to the Eden Park Reservoirs. These connections were made in seriatim, the old pumps being put out of service, as their pump mains were being cut and connected with the new main, the new low service pumps gradually taking up the service of supplying the reservoirs and the old intermediate service until June 16, when the new pumps assumed the entire service. No trouble of any kind has been experienced with these mains, which is proof that the work, though surrounded with difficulties, was well done.

A final estimate on the first section was rendered on May 18, 1907, in the amount of $65,145.00, and on the second section on August 16, 1907, in the amount of $75,057.63, ten per cent of each of which was retained for a period of six months probation, during which time the work was to be kept in repair, and at the expiration of which the contractor was obliged to present a certificate showing that the street surfaces at that time were in a condition fully satisfactory to the Board of Public Service or its Chief Engineer. These certificates were furnished, and final payments respectively made on December 23, 1907, and January 21, 1908.

WESTERN HILLS PUMPING STATION.

A constant general complaint of inadequate pressure and insufficient supply received from the western section of the low and intermediate service districts and from all the outlying districts of the hilltop territory caused a thorough study to be made of the entire distribution system, which developed that there was ample cause for complaint in the almost entire absence of proper supply mains to the outlying districts, and in the fact that no precise system had been followed in the extension of the pipe lines. In many sections of the city the water mains were too small even to properly supply domestic service and very much more so for fire service. A further fact that the capacity of many of these mains had become greatly reduced by the gradual accumulation in them of mud and sediment only aggravated the unsatisfactory conditions of pipe dimensions, all of which emphasized the necessity of re-enforcing the system by the laying of suitable feed and supply mains into the outlying territory and of connecting these at proper points with the existing lines of water mains.

This study also demonstrated that certain high grounds west of Mill Creek could not be supplied at an adequate pressure by the high service pumps at the Main Station, but that it would be necessary to maintain a separate pumping station for this service, also that this in turn should be divided into two services, one for the Price Hill and Fairmount District and another for the Westwood territory and that lying north and northwest of Westwood, which covers the highest ground in the vicinity of Cincinnati, and that the pumps for these two services be housed in one building more centrally and suitably situated for that purpose than the existing pumping stations. With this purpose in view, a site was selected on the north side of Queen City Avenue and east of Shadwell Street, consisting of six lots, with a frontage of 110 feet on Queen City Avenue and the same frontage on Chatham Street and Harrison Avenue in the rear, with a 20-feet-wide alley along the east side of these lots. These lots were secured under options at the price of $14,720.00. The buildings on these lots were sold on March 24, 1905, for $245.00, and were promptly removed.

After the contract for the principal pumping engines for this station had been awarded, plans and specifications were, on December 22, 1905, submitted to and adopted by your Board for the construction of an engine and boiler house and chimney, which is known as the Western Hills Station.

On January 30, 1906, four bids were received for this work, which included all necessary grading, cement walks, paved alley and driveways, drains, electric lighting, plumbing, sodding, and other work. These bids in the aggregate varied from $51,920.05 to $64,276.30. The contract was awarded to Charles J. Close, of Columbus,

Ohio, who was the lowest bidder. The buildings (see Plate 81) are constructed of brick, trimmed with Rock Castle blue stone and covered with a tile roof supported on a steel frame. The entire exterior of the buildings above the water table, including the interior of the boiler room, are faced with impervious buff-colored pressed brick. The interior of the engine room is faced with white and buff-colored enameled brick and enameled terra-cotta.

The engine room and basement floors are 92 feet 8 inches by 54 feet 4 inches, and afford ample room for three 2½ million gallons pumping engines for the Price Hill and Fairmount service and two one-million gallons pumping engines for the Westwood service. The boiler room is 76 feet 9 inches by 36 feet, and besides providing sufficient room for all the boilers needed, furnishes space for a machine shop, storeroom, toilet room, and lockers.

The contractor was very slow in commencing work, and the progress was not very rapid until well into the summer season, the reason assigned being a difficulty in securing competent laborers. The work was very nearly completed in January following, when the contractor disappeared, leaving his business affairs in a very bad shape. Though the unfinished work did not represent a thousand dollars in value, yet it was of that character that it was necessary to finish this work to have the buildings in a serviceable condition. Formal notice, as was required by the contract, was served upon the Surety Company, after which the contractor was declared in default, and on April 12, 1907, the work was ordered finished by day labor and the cost thereof charged against the contract. The plumbing, heating, painting, carpenter, electrical, and other work was completed in that manner at a cost of $969.14. The total cost of this work, including some extra water pipe, drains, and hydrants was $53,445.84. The balance of $1,030.86 due the contractor was paid into Court by voucher on February 26, 1909.

In April, 1905, plans and specifications were prepared for the construction and erection of two vertical or horizontal, compound pumping engines, each having a daily capacity of delivering 2½ million gallons against a head of from 190 to 210 pounds per square inch, with boilers sufficient to operate the engines and auxiliaries at the Western Hills Pumping Station.

On June 2, 1905, sixteen bids were received, which were as follows:

Name of Bidder	Address	Amount
Platt Iron Works Co.	Dayton, Ohio.	$28,184.00
Platt Iron Works Co.	Dayton, Ohio.	29,384.00
Platt Iron Works Co.	Dayton, Ohio.	30,178.00

Name of Bidder	Address	Amount
Platt Iron Works Co.	Dayton, Ohio	$31,378.00
Camden Iron Works	Camden, N. J.	29,432.00
Camden Iron Works	Camden, N. J.	38,427.00
Camden Iron Works	Camden, N. J.	42,085.00
Laidlaw-Dunn-Gordon Co.	Cincinnati, O.	32,300.00
Snow Steam Pump Works	Buffalo, N. Y.	33,600.00
The Wm. Tod Company	Youngstown, O.	36,200.00
The Wm. Tod Company	Youngstown, O.	44,500.00
Marine Engine Co.	New York, N. Y.	36,300.00
Kilby Mfg. Company	Cleveland, O.	39,965.00
Allis, Chalmers Company	Milwaukee, Wis.	40,300.00
Holly Mfg. Company	Buffalo, N. Y.	54,500.00
Holly Mfg. Company	Buffalo, N. Y	60,500.00

The plans and proposals submitted with these bids covered five different types of pumping engines. The proposition of the Snow Steam Pump Works was the lowest which in every respect complied with the specifications, and provided for two horizontal, cross compound, high-duty, crank and flywheel pumping engines, with the engine located between the steam and water cylinders, which allowed of a very compact design. The duty guaranteed was 138 million-foot pounds per 1,000 pounds of steam. The proposition included two Erie City tubular boilers, equipped with Roney stokers. The contract was awarded to the Snow Steam Pump Works on June 16, 1905. In due course of time detail shop plans to the number of 233 were submitted, examined, and approved.

On May 15 and on September 4, 1906, supplementary agreements were entered into with the contractors, one providing for an additional large steel air chamber on the discharge main on the inside of the building at an additional cost of $670.00 and the other providing for a larger steel smoke flue to accommodate a future boiler and for facing the brickwork of the boiler settings with buff-colored pressed brick, at an additional cost of $875.00.

The erection of this machinery began before the building for the same was completed. One of the pumping engines was put into service on April 15, 1907, supplying water to Price Hill and Fairmount districts, and also to the Westwood Pumping Station, while the old Mt. Hope Station was temporarily shut down. The pumps operated very satisfactorily, and the supply and pressure throughout Fairmount and at the Westwood Station was greatly increased, but owing to the main leading to Price Hill being heavily tuberculated, the loss of pressure was so great in this rising main that the service was not satisfactory. The main was later cleaned by the

Water Department, and after some additional pipe were laid on Price Hill to improve the distribution from the new station, the Western Hills resumed supplying the Price Hill district on December 24, 1907, and the Mt. Hope Station was permanently closed.

On January 2, 1908, a twelve-hour test run was made of pumping engine No. 1, and two days later a similar test was made of No. 2. Both engines met the contract requirements as to capacity and duty.

The pumping machinery thereupon was given their two coats of paint of light gray color and covered with two coats of varnish. A final estimate, less $500.00, was rendered on January 14, 1908, and the balance of $500.00 was paid on July 31, 1908, after the painting was accepted. The total cost of this installation was $35,145.00.

As the supply to Westwood at present represents only about 10 per cent of the supply to Price Hill and Fairmount, it would be poor economy to raise the pressure at the pumps fully 30 pounds in order to supply Westwood by these same pumps. On investigation it was found that the two Laidlaw-Dunn non-condensing, direct-acting, horizontal, duplex pumps having each a capacity of half a million gallons per day, and located at the old Linwood Pumping Station, could be modified and strengthened to serve, when installed at the Western Hills Station, in supplying the Westwood district. Accordingly these pumps were taken apart and removed to the Laidlaw-Dunn-Gordon shops, where they were overhauled and strengthened, and changed so as to allow their being used either condensing or non-condensing. In connection with this change the condenser and a special air chamber from Mt. Hope Station were used. The concrete foundations for these pumps were put in by J. E. Gomien in July at a cost of $340.00. After the pumping engines had been refitted and tested they were erected on their foundations, and all water and steam-pipe connections were made by day labor. A 12-inch main which was previously laid from the building along the alley to Harrison Avenue, and along this street for a distance of 1,400 feet, was connected at this point with the old 10-inch main on Harrison Avenue, and together make up the main which is used to supply Westwood and the territory beyond. The work was far enough advanced to put the pumps into regular service on October 20, 1908, since which time the Westwood Pumping Station has been put out of service. No increase in the force at the station has been made necessary by the operation of these additional pumps. The service has been continuous and quite satisfactory, though the pumps are not large enough to instantly meet the demand of a large draught without undue racing.

In order to give the best service in the Westwood district and to relieve the pumps from excessive fluctuations in pressure and speed, caused by sudden heavy draughts, some means for the storage of water on the high ground at Westwood should be provided. The elevated tank which was formerly used in connection with the abandoned Linwood Pumping Station would in all respects answer as a storage tank for Westwood and the surrounding territory. The tank consists of steel plate, is 20 feet in diameter and 25 feet high, with a cone-shaped bottom 7 feet deep, and has a capacity of nearly 60,000 gallons. The steel tower which supports the tank is 70 feet high, and is just of the right height when erected on the highest ground to maintain the pressure at Westwood.

As the bills for lighting this station by electricity averaged from $85.00 to $90.00 per month, the electric light plant at the old Hunt Street Pumping Station, consisting of two Noye engines, operating two Nowotny six K. W. generators, was removed, thoroughly overhauled, and installed in the engine room. This plant has furnished the light for this station and the grounds since March 9, and the cost of lighting has since then been very materially reduced.

In July, 1906, plans and specifications were prepared for the construction of a coal house, storage house, and for coal-receiving bins to be located on the lots in the rear of the boiler house on the north side the alley and fronting on Montrose Street and Harrison Avenue, these streets being at this point 26 feet above the grade of the alley.

On August 10, 1906, three bids were received for this work, varying from $25,020.25 to $35,530.50, which included all necessary grading, driveways, curbs, scales, and other work. The coal-storage house is 64 by 62 feet, constructed entirely of re-enforced concrete, and contains twenty-five coal bins, supported upon the outer walls and on concrete girders supported by concrete columns, the lower sections of the bins consisting of hoppershaped pockets, each equipped with a coal spout and a 16-inch square double cut-off valve, so as to allow over 6½ feet head room above the tracks and floor. The floor is on a level with the boiler house floor, and a 21½-inch gauge track connects the same with the tracks under the coal hoppers. The roof over the coal bins is also constructed of re-enforced concrete, and carries on concrete beams five lines of tracks over the center of the coal bins to the receiving bins which are located north of and above the coal-storage bins.,

A storehouse 16 x 13½ feet in size, also constructed of concrete, adjoins the coal-storage house, and is provided with a track and a forge and tool room.

The contract was awarded to the J. B. Wilson Concrete Co., who were the lowest bidders. At the request of the contractors, a supplementary agreement was entered into on August 28, 1906, substituting, at a reduction of $1,500.00 in the contract price, re-enforced concrete for the steel plates of which the twenty-five coal hoppers were to be constructed, the lower section of the concrete hoppers to be faced with ⅜-inch steel plates. This change was made because of the inability of the contractors to secure the delivery of the steel-plate hoppers at an early date. Notwithstanding this concession the work progressed in a very slow and unsatisfactory manner. The work was not completed until in spring of 1907. A final estimate was rendered on July 2, 1907, amounting to $25,818.03. The capacity of the coal bins amounts to about 500 tons, or about four months supply.

RE-ENFORCEMENT OF THE DISTRIBUTION SYSTEM.

The manifest general inability of the existing water mains throughout the city, and particularly in the outlying districts, to furnish an adequate supply and pressure for either domestic or fire service, as evidenced by numerous complaints received from all parts of the city, made it obvious that there was as much need in the betterment of the distribution system as in the pumping machinery of the old Works. A thorough study of the existing pressures and of the probable future needs in the various business, factory, and residence districts of the city, indicated the lines of greatest deficiency and the amount of re-enforcement required by the laying of large supply or feed mains. A general plan of re-enforcement was outlined and approved, and in order that consumers might have the earliest possible benefit of such betterment without awaiting the completion of the new Works, the necessary surveys, plans, and specifications were made and the work advertised. Considerable difficulty was had in finding streets, especially in the business districts, where the entire area under the street surfaces was not already occupied by sewers, gas and water mains, electric light, railway and telephone conduits, fire cisterns, pull-boxes, and manholes, of the greater part of which there were no records, but which had to be located by surveys and examinations. Quite a number of the most desirable routes for large mains had to be abandoned because it was impossible to find sufficient continuous unoccupied space in which to lay them. As it was, many of the new mains had to be swung from one side of the street to the other; in other cases gas mains and conduits had to be moved, while service connections were almost constantly relocated.

Plans and specifications for the necessary cast-iron pipe and special castings were prepared, approved, and bids invited. These included sizes varying from 4 to 48 inches

in diameter. On May 3, 1904, but one bid was received for this pipe, which was $25.45 for straight-socket and spigot pipe, and the total bid of which aggregated in the sum of $658,180.00. This bid was rejected and new specifications were prepared which divided the pipes into classes according to the pressures to which they would be subjected, and calling for a high grade of iron to reduce the weight. The pipes and castings were to be cleaned before coating by the use of sand blast.

On July 1, 1904, two bids were received, which were as follows on the items as called for:

Name of Bidder.	Address.	30" to 48" Pipe.	30" to 48" Specials.	Sand Blasting.	Aggregate
U. S. Cast Iron Pipe & Fdy. Co.	New Jersey	$24.40	$85.00	$ 1.00	$185,820.00
Dimmick Pipe Co.	Birmingham, Ala		69.45	4.50	

The bid of the Dimmick Pipe Company was informal, as it did not include a bid for the straight pipe.

Name of Bidder.	Address.	4" to 24" Pipe.	4" to 24" Specials.	Miscellaneous.	Sand Blasting.	Aggregate.
U. S. Cast Iron Pipe & Fdy. Co.	New Jersey	$24.40	$80.00	$85.00	$2.00	$243,060.00
Dimmick Pipe Company	Birmingham, Ala.	24.50	53.50	62.50	4.50	253,550.00

The U. S. Cast Iron Pipe & Foundry Company also submitted an alternative bid of $23.85 for all straight pipe on condition that the contract be awarded to them in its entirety. This reduced their aggregate bid on all items $7,810.00. The contract was awarded to said company, they being the lowest bidder, following which, on August 5 a supplementary agreement was entered into, modifying the price for straight pipe to $23.85 per ton, in accordance with the alternative bid, which brought the aggregate price of the bid down to $421,070.00. The manufacture and delivery of the different sizes of this pipe and specials were largely timed so as to be in conformity with the requirements of the contractors who were laying the different pipe extensions. What pipe could not be promptly used was stored at the yards of the company at Addyston until it was needed. It becoming apparent that a larger amount of extensions would be made than was originally anticipated, your Board on July 25, 1905, availed itself, on account of the low contract price of the pipe, of the right to increase the amount of pipe required under the contract. The time for the delivery of the pipe was extended several times, finally to April 1, 1907, by which time practically

all the pipe had been manufactured, though not all delivered. The final payment was delayed until some differences in the accounts on January 24, 1908, were adjusted. The total payments under the contract amounted to $425,011.40.

On June 28, 1904, seven bids were received for the manufacture and delivery of 156 gate valves, varying from 4 to 48 inches in size, and to be used in the extension of mains. These bids varied from $13,577.75 to $21,635.00 in amount. All of the proposals, with the exception of that of the Coffin Valve Company, of Boston, were informal, as they were not accompanied with blue prints or plans and specifications describing the valves which were to be furnished. The contract was awarded to the Coffin Valve Company at the prices bid in their proposal, which aggregated to the amount of $19,795.00. The company proposed that if the time for the delivery of the three 48-inch and the five 42-inch gate valves could be extended three months, or until July 1, 1905, they would agree to a reduction of $1,000.00 in the aggregate price of their contract. This proposition was accepted, and on August 5, 1904, a supplementary agreement was entered into to that effect. For the same reasons as above stated, the number of valves to be furnished under the contract was increased to meet the requirements of added extensions. The time for the delivery of all the valves was extended several times, and finally to October 1, 1905, at which time all but two 30-inch valves had been delivered. The final payment was made on December 15, 1905, and the total cost of the work amounted to $26,056.00.

In July, 1904, plans and specifications were prepared for the laying of mains on various streets. As far as it was possible, all uncertain features of work which might arise in connection with the work were eliminated. Unit prices were called for on all classes of work which it was known would be encountered, and cost price, plus 15 per cent was specified for work which could not be anticipated. The specifications were made very definite as to what each price should include.

In order to insure a perfect restoration of all street pavement and surfaces disturbed in the laying of the water pipes, the contractors were compelled to submit a certificate from the Board of Public Service or its Chief Engineer that the same had been replaced and restored to their satisfaction, for which purpose said Board appointed its own inspectors to supervise the work of restoration, who, however, were paid by your Board. This certificate was presented in each case where final payment has been made. In some instances these payments have not yet been made, as the times for the maintenance of the street pavements have not yet expired. These cases will, however, be finally adjusted and disposed of before the Works are turned over to the Board of Public Service.

Twenty-seven contracts were let from August 5, 1904, to the present time for the laying of supply mains in different parts of the city, varying from 48 inches in diameter to less. The competition in bidding for this work was nearly at all times quite strong and close. The results of the bidding on all this work are not given here in detail, as it would occupy considerable space, and as the same has been published in the Annual Reports. The contracts will be found listed in the Table of Contracts in Appendix "A," and the following table states the streets and sizes and lengths of all mains laid, including the pump mains from the Main Pumping Station, the order being that in which they were laid.

The Board of Public Service having at different times notified your Board that certain streets were to be improved, so that any extension contemplated on such streets might be made before the work of improving such streets was commenced, your Board took the liberal view that aside from any supply mains, if it were desirable to lay water pipes or larger mains in streets that were to be permanently improved with a pavement laid on a concrete base, it would approve of the laying of such water pipes or larger mains, so as to avoid the possible tearing up of such pavement in the near future. To meet this view, contracts were let in 1905 and 1906 for laying 6, 8, 10, and 12-inch water pipes in such streets as your Board might from time to time order laid during each of these years previous to the improvement of such streets. Quite a number of lines of pipe were so laid, all of which are included in the following table:

Street	From	To	Size Inches	Length Feet
Madison Road	Near Paul Street	Observatory Avenue	20	2458
Observatory Avenue and Herschel Avenue	Delta Avenue	Principio Avenue	10	4088
Woodburn Avenue	McMillan Street	Madison Road	36	1904
Madison Road and Hackberry Street	Woodburn Avenue	Hewitt Avenue	24	3362
Forest Avenue	Reading Road	Burnet Avenue	24	2751
Forest Avenue	Burnet Avenue	Carthage Pike	20	3701
Burnet Avenue	McMillan Street	Forest Avenue	24	7149
Woolper, Clifton, McAlpin and Lafayette Avenues	Carthage Pike	Ludlow Avenue	20	6534
Setchell Street	End of old 4 inch Pipe	Humbert Street	6	514
Humbert Street	Strader Street	Setchell Street	6	169
Strader Street	Near Wool Street	Humbert Street	6	557
Watson Street	Near Eastern Avenue	Humbert Street	6	870
Noble Court	Linn Street	West	6	279
Paddack Road	Reading Road	Ross Avenue	12	4514
Queen City Avenue	Tillie Street	Corporation Line	6	1016
Park Avenue	McMillan Street	Windsor Street	10	1381
Reading Road	Forest Avenue	Mitchell Avenue	24	3595

Street	From	To	Size Inches	Length Feet
Reading Road	Mitchell Avenue	Paddack Road	16	1433
Ellison Avenue	Linwood Road	Totten Avenue	6	1348
Carthage Pike	Mitchell Avenue	Corporation Line	12	1171
Oak Avenue	Liberty Street	Latham Avenue	6	1242
Innes Avenue	Near Bruce Av. & Ella St	Near Pullan Ave. & Chase Avenue	6	279
Cutter, Wade and Faulkner Streets	Ninth Street	Western Avenue	42	5601
Mitchell Avenue	Carthage Pike	Miami Canal	16	1293
Linwood Road	Near Delta Avenue	Near Paxton Road	8	2632
Wade Street	Cutter Street	Central Avenue	20	780
E. Court Street	Russell Street	Gilbert Avenue	6	2250
Carthage Pike	Forest Avenue	Mitchell Avenue	20	4466
Western, McLean and Spring Grove Avenues	Faulkner Street	Queen City Avenue	36	4718
Spring Grove Avenue	Queen City Avenue	Draper Street	30	648
Draper Street	Spring Grove Avenue	Colerain Avenue	24	648
Eggleston Avenue and Ninth Street	Eight Street	Elm Street	48	3626
Ninth Street	Elm Street	Cutter Street	42	2606
Linwood Road	Near Forest Avenue	Delta Avenue	10	4274
Warsaw Avenue	Near Wilder Avenue	Near Underwood Avenue	6	2080
East Twelfth Street	Main Street	Broadway	8	828
Mound Street	Ninth Street	Clark Street	10	1380
Seegar, Knox & Blaine Sts	Harrison Avenue	Fairmount Avenue	10	1502
Ludlow, Dodsworth and Hamilton Avenues	Lafayette Avenue	Blue Rock Street	20	4424
Dayton Street	Central Avenue	Whiteman Street	8	772
Queen City Avenue	Spring Grove Avenue	Western Hills P. Station	30	4569
Queen City Avenue	Western Hills P. Sta	Shadwell Street	20	576
Hewitt & Woodburn Aves.	Hackberry Street	Langdon Avenue	24	3987
Eastern, Columbia and Humboldt Avenues	Main Pumping Station	Woodburn Avenue	48	6063
Eggleston Avenue and Third Street	Eighth Street	Near Third Street Res'v'r	48	2615
Madison Road	Observatory Avenue	Edwards Road	16	4316
Eastern Avenue and Third Street	Main Pumping Station	Martin Street	60	11969
Grand and Warsaw Aves	Glenway Avenue	Hawthorne Avenue	12	1599
Price Avenue	Hawthorne Avenue	Elberon Avenue	8	1005
Langdon Avenue	Woodburn Avenue	Gilbert Avenue	20	1829
Langdon Ave., Duck Creek Rd., Ivy & Fairview Aves	Gilbert Avenue	Madison Road	16	6522
Hulbert Street and Freeman Avenue	Western Avenue	Findlay Street	20	1030
Freeman Avenue	Wade Street	Kenner Street	16	896
Mound Street	Ninth Street	Eighth Street	20	248
Mound Street	Eighth Street	Van Horn Street	10	156
Liberty Street	Faulkner Street	State Avenue	24	4952
Harrison Avenue and Engle Alley	Seegar Street	Western Hills P. Station	12	1552
Queen City Avenue and Quebec Road	Shadwell Street	Glenway Avenue	16	9022

The total amount which was expended on account of the betterment and extension of the distribution system, not including the pump mains, was $883,893.61, of which $472,949.45 was for pipes, specials, and valves, $25,603.05 for hauling same, and $385,341.11 for laying mains, inspection, and incidentals.

A very marked improvement in both supply and pressure was observed immediately after each line of supply main was put into service, in some instances the pressure in the old mains being increased from 42 to 52 pounds per square inch above its former pressure. In the plan of re-enforcement for the hilltop district, these mains were so connected with each other as to form complete circuits, so that the supply was not dependent upon a flow from one direction only, as was generally the case in the old system, where in some instances areas of two and more square miles depended upon its supply from one single connecting main. This condition was caused and in a measure still exists on account of the exceeding great number of dead ends on the mains, a condition which has other serious disadvantages as well.

In the course of time the loops of some of these supply mains in the outer territory should be completed, for which connections have been provided in the mains when these were laid, the principal one of which is a 30-inch main in the low service from the Main Pumping Station eastward on Eastern Avenue to Red Bank, thence along Red Bank Road to Madisonville, branching westward along the low grounds to Oakley and Norwood, with the view of supplying the low territory which of necessity is now supplied by the high service. This main might be extended along the B. & O. S.-W. Ry. to a connection with the low service main in Spring Grove Avenue, thus forming a loop around the entire city.

In many parts of the lower and business sections of the city, especially in the western portion, the many four and six-inch mains should gradually be replaced or supplemented by eight, ten, and twelve-inch mains to furnish a better pressure to the consumers and a greater supply for fire protection purposes, which is now inadequate in case of large fires or of a conflagration. These larger mains can be easily fed by the large supply mains which were laid by your Board.

In the Annual Report for 1906, the President, Mr. August Herrmann, called attention to the fact that as the work was approaching completion it became evident that the money available would not be sufficient to complete the work as an entirety and in all its details, and reviewed the expenditures to date, the amounts which would become due on the completion of all existing contracts, and the amounts required to complete the work and to pay for any bonus that may possibly be earned by the pumping machinery at both the River and the Main Pumping Stations, the extension of

the distribution system, the cost of operation, and other miscellaneous matters, and concluded with the recommendation that a joint meeting be called with the city officials and committees from the Council and all the various business and other organizations in the city, for the purpose of presenting a full statement of the conditions of the work, and to discuss the best means of providing the necessary funds. This recommendation was adopted, invitations issued, and such a meeting held in the Council Chamber on the afternoon of February 16, 1907, which was very largely attended. A full discussion was had, and the whole matter referred to a special committee of ten prominent citizens, appointed by the Mayor, who were to ascertain whether there was any necessity for the raising of $1,000,000 or any part thereof, and if so, to devise ways and means for raising said money.

This Committee, after organizing, made a personal inspection of the several pumping stations, the filter plant, and other work under progress, and familiarized itself with the magnitude of the work, and at a number of public meetings held at various times, by witnesses and otherwise, collected such information as was deemed desirable to enable the Committee to formulate the report on the matter referred to it.

The Committee, at a meeting called for that purpose by the Mayor, submitted its report, recommending that funds should be provided for such work as was necessary and for some further additions thereto which had been planned, but on account of a lack of funds had been omitted, which, however, appeared to the Committee to be desirable to carry out in the interest of economy of operation.

On December 30, 1907, and on May 18, 1908, the Council by ordinance, under the general law, authorized the issue of bonds to the amount of $750,000.00, to be used in completing the work, in paying any bonus that may be earned and for other miscellaneous items.

OPERATION OF THE NEW WORKS

The impaired condition of nearly all the pumping machinery in the old principal pumping stations for the high and intermediate services, when operated beyond their rated capacity, caused the same to become so frequently disabled to such an extent as to create a shortage in the supply of both services, especially in that for the hilltops. To relieve the existing conditions in a measure, and as soon as possible, one of the pumps at the River Station and one of the high service pumps at the Main Station were put in condition for service at the earliest possible moment after the erection of the same had commenced, in order to assist in supplying water to the hilltops and incidentally to the intermediate service through the Eden Park Reservoirs, whenever the breaking down of the old pumps should cause any deficiency in the supply of water. Other parts of the work, necessary to the delivery of water from these pumps were also crowded forward to a condition which permitted of their being utilized in supplying water before their completion. In October, 1906, this work was advanced sufficiently, in accordance with the promise made earlier in the year by your Board to the Mayor and the Board of Public Service, to pump twelve million gallons of water daily into the high service system should the disability of any pumping engine at the old Works make it necessary to do so.

In anticipation of being called upon to assist in supplying water to the city, specifications were prepared for the delivery of 65,000 bushels of Pittsburg nut and slack coal to the River Station and 85,000 bushels of like coal to the Main Station, the coal to be delivered from barges into dump cars at the foot of the inclined tracks at each station, and to be subject to calorimeter tests, no coal to contain less than 13,000 B. T. U. per pound of coal. On June 15 only one bid was received, being that of the Monongahela River Consolidated Coal & Coke Co., who proposed to furnish the coal according to specifications at 6½ cents per bushel. The contract was awarded to said company. A barge load of from 13,000 to 14,000 bushels was delivered at each station during August, and the total amount of 159,629 bushels was delivered by the end of December, 1906, at a total cost of $10,388.89.

The first water was pumped to consumers on the hilltops on October 6, 1906, and on various days thereafter, but not to any great extent until from and after January 1, 1907, when two of the high service pumps went into regular commission, oper-

ating at about half-speed until January 20, since which time all of the water for the hilltops has been supplied by the new pumps from the Main Station. From this time on the new Works gradually assumed the duty of supplying the water and displacing the service of the pumps at the Front Street, Eden Park, Hunt Street, Linwood, Cumminsville, Mt. Hope or Price Hill, and finally Westwood Pumping Stations.

At the River Pumping Station one of the thirty-million gallons pumping engines was put into service on the morning of January 1, 1907, delivering water direct through one of the 60-inch pump mains and a temporary by-pass connection into the clear-water basin, which was filled and used as a supply basin to the gravity tunnel, which in turn supplies the pumps at the Main Station. This method of delivery was continued until March 4, 1907, when the pumps began to deliver the water into Settling Reservoir No. 1, after which time, until the filter plant was put into service, the clear-water basin was supplied from the reservoir instead. One or the other of the two pumps which were in running condition were operated a sufficient number of hours each day to meet whatever amount was being pumped at the Main Station.

During the year 1907, by an agreement with the contractors for the pumping machinery, the pumping engines were run under the direction of their Superintendent of Erection and by engineers and oilers selected by him for that purpose, and who were paid by the contractors, who in turn were reimbursed such amount plus 10 per cent. This arrangement permitted the erection of the other pumping engines to proceed without interruption or without interference with the operation of the other pumps. All other men engaged in running the boiler plant, the electric generators, and of maintaining the station were employed and paid by your Board. On January 1, 1908, the engineers and oilers were transferred to the city service, and have continued in your employ ever since.

Owing to the fact that much of the work in connection with the pumping machinery at the several stations, and of many other contracts as well, had not yet been completed, the operation of all the different parts of the new Works was continued under the authority of your Board until all of the work should have been completed, and the entire Works, together with its operation, could be turned over to the Board of Public Service. The operation of the new Works was therefore continued with the understanding that at the end of the year and previous to the turning over of the Works, the City Water Department would reimburse your Board the amount expended by you in operating and maintaining the same.

This circumstance permitted the gradual elimination from among the employees of the several stations and of the filter plant those who, on account of a lack of proper

interest in their duties or of pride in maintaining a high class of service and the plant in the best of condition, or who on account of utter disregard of all discipline or rules and regulations, had become undesirable. Many and frequent changes became necessary, with the result that the personnel has been gradually brought to a higher plane and to a higher appreciation of the respective responsibilities and of the welfare and appearance of the plants, and to a recognition of the fact that competency and attention to duties and to the rules and regulations are the only merits which insured permanency of employment. With such class of employees only can the new Works be operated economically, successfully and creditably.

During the period of operation considerable work was done at all the stations in completing their equipment. All material and supplies, tools and furniture which could be used were taken from the old Front and Hunt Street Stations, as well as from Linwood Station, and distributed among the several stations of the new Works. Suitable machine tools were installed, and each of the stations was supplied with cupboards, lockers, and shelving for the care of tools and supplies. At the Main Station a separate pressure oiling system is being installed, which will produce a considerable saving in the cost of engine oil. Preparations are also being made to remove the two batteries of Babcock and Wilcox boilers from the Front Street Station to the boiler-room of the Main Pumping Station. A number of other improvements were also made in and around the several buildings, all tending to perfecting the Works.

At the River Station no difficulty has been had with the operation of any part of the installation. At times three of the pumping engines have been run at nearly their rated capacity without necessarily increasing the number of attendants, which at this station consists on each eight-hour watch of one engineer, four oilers, one fireman, and two coal-passers, in addition to which there is an Assistant Chief Engineer in charge of the station, resident at California, one clerk, one machinist and helper, one boiler cleaner, one locomotive operator, a janitor, and three or four laborers to take care of the grounds, or a total regular force of thirty-six employees. The total cost during 1908 of pay-rolls, fuel, oil, waste, supplies, repairs, and lighting the station and all the grounds around the works at California amounted to $3.28 per million gallons pumped into the settling reservoirs, making due allowance only for the electric current used for power and lighting purposes at the Filter Plant, and of one per cent for slippage in the pumps.

INTAKE PIER.

At the Intake Pier six men are employed looking after the screens, which require constant attention, the water at some stages of the river carrying so many leaves, twigs, and such an amount of fibrous matter that it is necessary to hoist and clean the screens once every half-hour. Some trouble was first experienced until the men, by the keeping of records, became acquainted with the condition of the river water at its various stages and the frequency of cleaning required to prevent the screens from clogging more than 25 to 30 per cent. Similar trouble is had in winter with the formation of needle ice on the screens during certain conditions of temperature, which, however, can best be overcome by sending a small jet of steam against the screens from a portable boiler, which is kept at the storehouse for that purpose, the raising of the temperature of the water by less than one degree being sufficient to prevent the formation of this ice. The storehouse at the shore end of the bridge has also been equipped with a few machine tools to facilitate repairs at the pier.

RESERVOIRS.

The delay in completing reservoir No. 2 until in October and the behavior of the reservoir lining during the draining of the reservoir prevented the placing of this reservoir in regular service until after the same had been again filled and closely examined for leaks and found to be in good condition. Up to that time reservoir No. 1 was in constant service, water being continuously pumped in and drawn out after not more than eight to ten hours sedimentation, the reservoir being almost constantly kept full or at about elevation 140.00 except during the tests of the pumping engines at the River Station, when this reservoir was drawn upon to supply the difference between the daily consumption and the pumpage of one engine.

From the daily examinations of the turbidities of the raw river water and of the settled water leaving reservoir No. 1, during months when the turbidity in the river water was above 100 parts per million, it is seen that an average of 48 per cent of the suspended matter is removed in passing through the reservoir. By the use of the two reservoirs a longer time for sedimentation can be secured with slightly better results.

The total available capacity of these two reservoirs is sufficient to permit a complete suspension for fully six days of any part of the Works between the reservoirs and the river, should such suspension ever become necessary or desirable. No such length of time will ever be needed to drain the intake or river tunnel, as it can be pumped out in from eight to ten hours time and cleaned out in that much additional time; however, it is well to have considerable latitude and reserve in all divisions of a Works of this magnitude.

Although reservoir No. 1 has, with the exception of about three weeks, been in constant service since March 4, 1907, it has not yet been cleaned, but it is expected that this spring, after No. 2 will have been put in service, it will be drained, flushed, and the mud deposit be removed by the means provided therefor. The most suitable time for cleaning these reservoirs is in the fall, when the river water carries very little sediment and the coagulation basins can remove the same without overtaxing the filter bed. The cleaning should not be delayed for so long a period as to make the removal by means of hose streams difficult.

The reservoirs should be constantly patrolled by watchmen, whose duty, among other things, should also be to report periodically to the pumping station and the filter plant the stage of water in either reservoir, as well as the observation of certain gauges erected by the Weather Bureau at the reservoirs.

FILTER PLANT.

On the completion of the head house, all the apparatus in the old laboratory near Eden Park Reservoir was removed to the new laboratories, and in the course of time this equipment was completed. As early in October, 1907, as the conditions would permit, a few of the filters were operated intermittently, and the apparatus in the chemical house, as well as the controllers, valves, and switches in the head and filter house were properly adjusted. Continuous filtration was commenced on October 22, and since November 1, 1907, the entire water supplied to the city has been filtered. A very close and constant inspection of the effluent from the filters has been maintained from the very beginning.

The following results of the operation of the plant for the year 1908 have been prepared by Mr. J. W. Ellms, Superintendent of the plant, and are considered under three different heads, showing —

1 — The quantities of water treated, filtered, used, wasted, and lost (by leakage); the amount of chemical coagulants applied; the operation of the settling reservoir, coagulation basins, filters, and clear-water basin, and the preparation of the chemical solutions.

2 — Chemical and bacteriological data obtained in examining the water from the Ohio River and its subsequent analysis after plain sedimentation, coagulation, and filtration.

3 — Cost of operation in detail and cost of filtered water.

1 — GENERAL OPERATION OF THE PLANT.

The quantities of water which have been handled by the filtration plant during the year have been classified, as shown in the following table, and are given in gallons:

1908	Water Treated	Total Water Filtered	Filtered Water Used for Washing Filters	Water Used Wasted & Lost By Leakage	Filtered Water Delivered into Service
January	1,248,962,059	1,244,340,969	37,840,000	5,582,090	1,205,539,969
February	1,188,301,426	1,181,313,386	52,102,680	7,887,040	1,128,311,706
March	1,259,389,001	1,242,909,331	58,949,868	18,440,670	1,182,998,463
April	1,215,934,926	1,218,176,916	49,481,000	9,188,010	1,167,765,916
May	1,245,068,389	1,222,322,089	35,200,000	16,697,300	1,186,171,089
June	1,404,474,627	1,400,538,587	34,920,000	4,866,040	1,364,688,587
July	1,471,162,333	1,463,007,523	50,331,538	9,115,810	1,411,714,985
August	1,520,368,891	1,514,628,941	50,938,705	6,700,950	1,462,729,236
September	1,487,462,298	1,480,839,038	51,706,860	7,553,260	1,428,202,178
October	1,410,093,479	1,402,664,779	71,632,000	8,389,700	1,330,071,779
November	1,281,531,797	1,257,334,627	50,013,350	27,627,170	1,206,391,277
December	1,288,175,653	1,281,340,723	57,866,270	7,795,930	1,222,513,453
Totals	16,020,924,879	15,909,416,909	600,982,271	129,843,970	15,297,098,638

The greatest quantities of water were filtered during the summer months, as would naturally be expected. During March, April, May, and November the coagulation basins and clear-water basin were cleaned, which accounts for the greater losses of water during these months. The filtered water used for washing the filters was somewhat increased during the last six months of the year on account of the very large amount of microscopic plant and animal life which was present in the river and settled water, and caused the filters to clog more rapidly and hence necessitated more frequent washing.

The following table shows the average stage of the Ohio River for each month, the average percentage of removal of turbidity from the river water by the settling reservoir, and the average amount of sulphate of iron and of lime applied to the settled water.

1908	Average Stage of the River In Feet	Turbidity in parts per Million.			Average Grains per Gal.	
		Of River Water	Of Settled Water	Percentage Removal	Sulphate Of Iron	Lime
January	21.9		85	46.5	1.14	0.74
February	32.3	430	230	46.3	2.02	1.15
March	42.1	410	220	41.1	2.30	1.19
April	35.6	255	150	53.7	1.99	1.07
May	30.7	270	125	52.6	1.75	0.93
June	12.8	190	90	52.5	1.14	0.78
July	10.1	200	95	52.5	1.32	0.88
August	8.6	145	85	41.4	1.33	0.80
September	4.4	11	9	18.2	1.15	0.69
October	3.6	7	6	14.3	1.36	0.85
November	4.7	50	31	38.0	1.56	0.92
December	6.8	93	33	65.3	1.59	0.89

The highest stage of the river, and consequently the most turbid water, occurred during the months of February, March and April. A fairly high stage of water existed during January, but on February 20 the river reached an elevation of 51.30 feet; on March 11 it again rose to a height of 53.30 feet, and again on April 4 to a height of 55.90 feet, the latter being the highest elevation reached during the year.

The average amount of sulphate of iron applied per gallon for the year was 1.53 grain, and of lime 0.89 of a grain. This corresponds to 26.1 and 15.2 parts, respectively, by weight in a million parts of water.

No serious trouble has been encountered during the year in the application of the chemical solutions to the water. The primary application of the solutions has been made to the water flowing through the head house and in Valve Chamber "B." With only one or two exceptions this has produced the proper degree of coagulation. Secondary application of the solutions, when the first application was not quite sufficient, was made in Chamber "E" prior to the passage of the water through basin No. 3, or sometimes just before it flowed to the filters. Incomplete coagulation has never been but of a few hours duration, and has always been quickly remedied by this additional application of chemicals. It has enabled the amount supplied to be kept within much narrower limits than would be the case if a secondary application were impossible.

The aim in the operation of the coagulation basins has been to produce in them as great a deposit of suspended matter as was possible. The turbidity of the water passing to the filters has usually been quite low. For the whole year it averaged about 32 parts per million, although during the flood periods it ranged from 40 to 75 parts per million. The residual suspended coagulated matter is usually in a finely divided state when it reaches the filters; but as a rule no marked tendency for this material to break through the sand beds has been observed. Ample periods of sedimentation have shown their value in the decreased amounts of chemicals which it is necessary to apply. With the present consumption of water from eight to ten hours sedimentation in the coagulation basins are possible when using both of the large basins, and which are utilized in the normal operation of the plant. About 67 per cent of the plain settled water turbidity is removed in these basins, or 34.6 per cent of the original river water turbidity. An average of 17 per cent of the river water turbidity passed to the filters to be removed.

The sediment which accumulated in the coagulation basins was removed twice during the year. In March basin No. 1 was cleaned, and in April basins No. 2 and No. 3. Cleaning was again undertaken in November, during which month all three basins were drained seriatim and the mud washed out. The sludge at the end of the drain-

ing process is from two to three feet deep over most of the bottom of the basin. Underlying this is found a semi-solid deposit varying in depth from five to six inches at the outlet end of the basins and from two and three feet at the inlet end. The draining of the large basins takes from 10 to 11 hours, and the flushing requires the services of six men for about twelve hours. The small basin of two million gallons capacity is drained in about three hours, and flushing requires about the same time.

The following table contains certain data collected in connection with the operation of the filters:

1908	Total Number Filtering Hours	Average Period of Service, Hours	Total Number of Filter Washings	Average Time Required to Wash a Filter in Mins	Percentage of Wash Water
January	7,199	15.09	473	3.76	3.04
February	7,014	11.72	588	4.30	4.41
March	7,248	11.11	649	4.66	4.74
April	7,241	15.16	472	5.22	4.06
May	7,445	21.39	352	5.47	2.88
June	8,417	22.04	388	5.17	2.47
July	9,150	13.00	707	4.43	3.44
August	9,243	16.44	565	4.71	3.36
September	8,911	14.45	622	4.64	3.49
October	8,476	11.60	740	5.41	5.10
November	7,679	14.34	549	4.87	3.97
December	7,783	12.26	674	4.40	4.52

The length of service of the filters between washings naturally was in inverse ratio to the turbidity of the water until in July there began to develop conditions which seriously interfered with the effective periods of service of the filters, and which could not be attributed to the turbidity produced by suspended clay in the river or settled water.

During the unusual and long-continued low stage of water in the river after the month of June, conditions were produced which were most favorable for the development of microscopic plant and animal life, which flourished in both the river and settled water. While coagulation and subsidence assisted somewhat in reducing the quantity of organic matter, which passed to the filter beds, it could not eliminate it entirely, and as a result the filter sand at the surface rapidly acquired a gelatinous coating through which the water passed with great difficulty. Frequent and prolonged washing of the sand beds was the only remedy that was applied, and, in consequence, the percentage of wash water was considerably increased. This increase was most marked in October. The organic matter choked the beds far more rapidly than did the suspended clay filtered out during the spring flood. Periods of service of filters, when these growths were most abundant, frequently fell to 4.5 or 5 hours.

Of the microscopic plant forms in the river water, eighteen different genera of the Diatomaceae were noted, and practically the same number in the settled water. Large numbers of Navicula, Asterionella, Synedra, Fragillaria, and Melosira were observed in both cases. The Chlorophyceae were represented by eighteen genera in the river water, and by twenty-three different genera in the settled water. The more common form present consisted of Botryococcus, Protococcus, and Ulothrix. In the coagulation basins the number of organisms diminished considerably, but the diatoms and algæ still predominated. While the water containing these plant forms had the characteristic vegetable odor, at no time did the predominance of any form known to give markedly disagreeable odors, give any trouble on this account. Representatives of all other classes of microscopic plant and animal forms, common to surface waters, such as the Cyanophyceae, Protozoa, Rotifera, Crustaceae and Spongidae, were frequently observed.

About the middle of April the presence of microscopic plant life was discovered in the clear-water basin. This basin having been used as a storage basin during the period that untreated river water was supplied to the city, prior to the completion of the filter plant, contained, in consequence, a considerable deposit of mud. On May 30 and 31 the basin was drained and washed. Two weeks after draining this basin it was found to have been seeded again with microscopic organisms. While no very marked disagreeable odors were detected, the presence of enormous numbers of these minute plant and animal forms produced a slight turbidity in the water. Diatoms and algæ predominated, the same as in the river and settled water. A very large growth of Encyonema was at one time observed, and algæ forms were at all times present.

The cause for these growths was the same as for their appearance in the river and settled water. The clear, filtered water permitted the passage of the sun's rays through seventeen or eighteen feet of water, and the increased temperature resulting, together with the light, made conditions extremely favorable for their propagation, once the open basin becoming inoculated with the organisms which had been floating about in the air. While certain of these plant and animal forms produce marked odors, and their decomposition frequently offensive odors in natural waters, those which predominated in the filtered water basin gave no trouble of this kind.

In order to avoid sending filtered water to the city which contained this microscopic plant life, the clear-water basin was by-passed, and the water sent directly from the filters to the shaft of the gravity tunnel which supplies the Main Pumping Station. This method of operating enabled the city to be supplied with clear water free from plant and animal life, in spite of the conditions existing in the clear-water basin, and at the same

time checked the growth of certain forms of plant life in the basin, for it was noted that when the water flowed through the clear-water basin the larger algæ forms grew more rapidly and abundantly than when the water was not in motion.

As the method of agitating and washing the sand of the filters in this plant is a marked departure from the established practice, a report of the results obtained will be of interest. The general method of the application of wash water and its effect in agitating the sand have been heretofore described. The experimental work upon which this method is based is briefly summarized in Appendix "C" of this report.

As a result of a few trials during the early part of the year, it was found that if the wash water was applied at the rate of two cubic feet per minute per square foot of filter sand area, an adequate agitation of the sand was effected and a proper cleaning of the sand grains produced. In consequence, all the wash water valve limit switches have been set, so as to allow the valves to open the proper distance to supply water at this rate.

The height to which the sand rises, when applying the water at different rates is shown by the following table of results determined from a number of tests made for that purpose.

Filter Number	Wash Water Cubic Feet per Minute per Square Foot	Distance sand rises above normal level in inches		
		A very few small sand grains	A small quantity of sand	Main Body of sand
23	2.00	12.25 to 29	11.50	10.25
19	2.05	13.25 to 29	11.50	10.25
1	2.08	14.00 to 29	13.25	12.25
1*	2.18	15.00 to 30	14.00	13.25
21*	2.37	23.75 to 30	21.50	18.00

*Limit switches changed to produce above rates of flow.

These figures are fairly consistent in themselves, and show quite plainly the height to which the bulk of the sand rises under the different rates of wash water as applied.

In order to learn whether any loss of sand was produced by this method of washing, a number of fixed points were marked on the concrete beams above the sand beds of nearly all the filters. Measurements were made of the distance from these points to the normal level of the sand surface below. A level rod with vernier was used in making the measurements. A series of readings were made for both halves of nearly all the filters, and a second series about seven months later. The results obtained show that within the limits of accuracy of this method of measurement, practically no sand was lost during that period of time, during which some of the filters were subjected to over 200 washings.

An examination of the sand bed showed that the sand is subjected to a very remarkable hydraulic grading, and that a very marked stratification of the sand is produced.

The condition of the sand at different depths is shown by the following table. The samples of sand were taken from one of the filters just before and after washing.

Sample taken at	Nitrogen as Albuminoid Ammonia, in parts per million		Bacteria per gram	
	Before Washing	After Washing	Before Washing	After Washing
Surface	121	103	330,000	99,000
1″ below surface	104	87	99,000	11,500
3″ below surface	90	81	84,000	11,000
5″ below surface	64	67	46,000	6,200
10″ below surface	37	46	27,000	.....
15″ below surface	.....	.....	12,500	6,400
25″ below surface	.....	.....	1,500	500
30″ below surface	25	19	800	300

These results appear normal considering the excessive amount of organic matter which the filters removed during the summer months and after being in service for about fourteen months.

The preparation of the chemical solutions has offered no serious difficulties, and the apparatus, as designed, has been found quite adequate with but few minor changes.

The filtered water used for slaking the lime is heated to a temperature of 140 degrees Fahrenheit. It flows through the slaking tank at the rate of 1.5 cubic feet per minute. The temperature of the milk of lime rises to about 150 degrees Fahrenheit as a result of the slaking process.

At the present rate of consumption of water it is not necessary to use more than one of the four lime-water saturators. For short intervals, however, two have been used. The water flows through the saturator at the rate of one million gallons per day, the supply coming from the settling reservoir.

The filtered water used to dissolve the sulphate of iron flows through the tank continuously at the rate of 2.5 cubic feet per minute. The rate of flow is not varied for any change in the rate of dumping the solid sulphate of iron into the tank, unless the interval is less than thirteen minutes between the application of two 100-pound bags of the chemical, in which case a second tank is put into service. Cold filtered water is used for dissolving the iron sulphate.

The uniformity of the strength of the iron sulphate solution is shown by the following table of results, obtained between the dumping of two successive sacks of 100 pounds each:

Sample Taken	Grains per Gallon $FeSO_4$, 7 H_2O.
1 minute before dumping	2,601
2 minutes after dumping	2,695
4 minutes after dumping	2,731
6 minutes after dumping	2,731
8 minutes after dumping	2,763
10 minutes after dumping	2,763
12 minutes after dumping	2,731
14 minutes after dumping	2,666
16 minutes after dumping	2,631
18 minutes after dumping	2,601

The efficiency of the method of applying the lime to the water is shown by a thirteen-day test, during which the plant was operated in the usual manner, except that a careful record of the weight of the sludge removed from the slakers was kept, and the volume of water used in slaking and dissolving the lime was noted. Analytical determinations were made on samples of the lime water and on mixed samples of the sludge to determine their character.

	Pounds	Percent
Weight of lime applied to slakers	70,700	
Insoluble matter present in lime	11,383	16.1
Weight of wet sludge, (24% water)	10,505	
Weight of dry sludge	7,984	11.3

The distribution of the losses which result from slaking the lime and dissolving it in settled water and the available lime which remains for actual treatment of the main body of settled water, is shown by the following table:

	Pounds	Percent
1. Soluble lime in lime water applied to raw water	54,728	77.4
2. Soluble lime used up by the raw water required for making lime water solution	2,834	4.0
3. Soluble lime in dry sludge taken from slaking tanks	1,755	2.5
4. Insoluble material in sludge from slaking tanks	6,229	8.8
5. Insoluble material presumably carried into saturator tank with milk of lime	5,154	7.3
Total	70,700	100.00
Percentage of the total available soluble lime in lime water solution applied to raw water		92.2
Average strength of lime water solution equals 28.8 grs. of CaO		

The variations in the character of the Ohio River water during the year 1908 were extremely marked, and afforded an excellent opportunity for testing the suitability of the plant for the purpose for which it was designed.

At all stages of the process of purification the water has been carefully and continuously subjected to examination in the laboratories. For this purpose 8,655 partial sanitary chemical analyses have been made and sixty-two complete analyses. In addition 4,747 bacteriological examinations were made, covering the routine determination of the numbers of bacteria present in river, settled, coagulated, and filtered water. The qualitative tests for specific organisms indicative of pollution numbered 898. Twenty samples of sand have been examined also, as well as 131 samples for microscopic plant and animal life.

The knowledge gained by the collection of this analytical data has been constantly utilized in governing the operation of the plant, and the labor involved has been amply justified both by the quality and cost of the filtered water.

The following table shows the chemical analyses as regards the mineral constituents only in the form of averages expressed in parts per million:

1908	Calcium (Ca)		Magnesium (Mg)		Iron (Fe)			Chlorine (Cl)		Sulphates (SO_4)		Residue on Evaporation			
Month	River Water	Filter'd Water	River Water	Filter'd Water	River Water		Filter'd Water	River Water	Filter'd Water	River Water	Filter'd Water	Total	River Water		Filter'd Water
					Susp.	Dis.							Susp.	Dis.	Dis.
January	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
February	.....	.....	.....	.....	.....	.....	.....	7.1	7.1	.....	.....	805	.....	.....	.....
March	.....	.....	.....	.....	10.2	.31	.11	7.0	6.9	.....	.....	505	410	95	112
April	10.1	12.3	3.8	5.7	6.3	.10	.10	7.2	7.2	16.6	29.0	239	137	102	109
May	.....	21.6	.....	4.2	10.5	.08	.08	7.9	7.8	.....	30.9	406	279	127	123
June	15.8	18.4	6.4	6.8	7.2	.09	.08	10.7	10.0	24.9	30.5	301	181	120	131
July	19.1	22.7	7.6	8.0	4.1	.07	.09	18.0	17.3	34.7	38.5	325	138	187	180
August	14.4	19.2	9.8	10.2	1.8	.16	.11	15.4	15.9	29.8	37.6	198	35	163	153
Septe'ber	15.6	26.8	12.7	7.0	.3	.10	.10	20.8	20.2	27.1	29.2	211	4	207	188
October	31.2	32.8	8.1	8.1	.2	.23	.20	26.9	26.5	33.1	39.5	211	4	207	218
November	12.3	19.2	10.6	8.6	2.5	.12	.12	23.1	22.1	22.4	28.8	173	28	145	151
December	18.6	23.8	10.3	9.5	2.7	.08	.06	32.7	31.3	34.4	46.8	227	26	201	209

The following table shows the weekly average bacterial counts in the river, settled, coagulated, and filtered water, and a few samples of water taken from a city tap, expressed in numbers per cubic centimeter.

1908 Average for week ending	River Water	Settled Water	Coagulated Water	Filtered Water	City Tap	Daily Efficiency Percent	Monthly Efficiency Percent
January 4							
11							
18							
25		11,000		500		96.9	96.9
February 1	12,500	7,800	1.700	300			
8	14,000	5,300	3,200	400			
15	45,000	17,500	3,900	750			
22	55,000	18,000	2,200	400			
29	12,000	7,300	1,100	95		98.5	98.5
March 7	20,500	5,800	800	85			
14	12,500	6,400	1,100	110			
21	12,000	4,000	800	75			
28	29,000	11,500	1,400	200		99.0	99.3
April 4	22,000	7,600	1,800	170			
11	10,000	4,800	650	120			
18	6,800	4,300	700	110			
25	4,900	2,900	450	55		98.4	98.9
May 2	8,200	2,700	750	85			
9	17,500	6,900	900	110			
16	11,500	7,800	1,200	100			
23	3,800	1,500	375	32			
30	3,400	1,900	300	40	110	98.9	99.1
June 6	2,500	1,900	350	110	150		
13	1,600	900	170	26	50		
20	1,500	800	240	55	35		
27	1,500	900	275	70	90	95.4	96.4
July 4	1,300	1,400	230	42	39		
11*							
18	1,400	1,000	110	55	65		
25	1,700	1,300	48	55	100	96.4	97.5
August 1	2,900	1,900	425	41			
8	8,100	2,600	225	23			
15	2,400	1,800	225	25			
22	475	425	90	13	22		
29	210	110	95	36	46	91.4	98.9
Sept'ber 5	650	110	70	20	14		
12	275	150	85	18	7		
19	250	65	49	24	28		
26	350	180	140	55	50	87.3	92.7
October 3	600	250	180	15			
10	450	190	140	25	41		
17	190	140	95	60	49		
24	180	90	65	17	34		
31	275	120	130	30	46	86.7	89.3
Nove'ber 7	1,200	275	200	42	46		
14	1,400	500	250	42	33		
21	950	475	400	55	55		
28	850	450	300	100	55	91.8	93.6
Dece'ber 5	450	275	130	110	70		
12	1,900	650	275	34	75		
19	2,600	450	180	21	18		
26	2,900	1,100	550	46	75	95.4	98.4
1908: Maximum	90,000	38,500	13,500	1,800	210		
Minimum	18	10	0	0	6		
Average	7,000	3,400	700	100	55		96.6

NOTE. *Most of the plates of this week were lost by liquefaction.

The yearly efficiency was 98.6 per cent. The average daily efficiency percentage for the month is the average of the percentage of removal of each day based on the comparison of the river water of that day with the filtered water of 8 A. M. the next day.

The average monthly efficiency is a comparison of the average daily number in the river water for that month with the average daily number in the filtered water. The average monthly efficiency for the year is the average of these, and the yearly efficiency is based on the yearly averages as shown. The following table gives the summary of the tests made during 1908 for Bacillus coli communis:

Presumptive Tests		River Water 1 c. c.		Settled Water 5 c. c.		Filtered Water 100 c. c.	
		Percent.	Number Tests.	Percent.	Number Tests.	Percent.	Number Tests.
With Dextrose Broth	Positive	60.8	28	50.5	30	28.9	11
	Negative and Doubtful	39.0	18	44.4	24	71.0	27
With Lactose Bile	Positive	60.7	96	64.8	109	35.9	32
	Negative	39.3	62	35.1	59	64.0	57
Partial and complete Confirmary tests made on samples giving positive presumptive tests.	Positive	51.0	18	40.5	15	48.1	11
	Negative	49.0	17	59.3	24	51.8	16

3—COST OF OPERATION.

In the operation of the purification plant the object has been to produce a water of the highest sanitary quality and at the lowest cost. The quality of the water produced has been shown by the data given in the preceding sections. The cost of producing this water is briefly summarized in the following table:

Coal, 1,448.46 tons	$3,201.10
Lime, 1,028.40 tons	6,342.11
Sulphate of iron, 1,754.15 tons	19,877.20
Express and freight charges, for returning empty sacks for chemicals	205.00
Repairs	617.95
Supplies	4,079.06
Legal advertising	228.13
Insurance, telephone rental and transportation	124.70
Water used, wasted and lost by leakage, 129.844 millions of gallons @ $3.28 per mill. gal.	425.89
Water used for washing filters, 600.982 millions of gallons @ $3.28 per mill. gal.	1,971.22
Cost of electrical power and light	5,299.95
Cost of labor and payrolls	24,828.07
Total	$67,200.38

There were delivered to the consumers 15,275.92 millions of gallons of filtered water during the year. On this basis the cost per million gallons was $4.40, while the cost for chemicals was $1.72 per million gallons, and formed 39 per cent of the total cost. The

labor represented 37 per cent of the whole cost, power 7.9 per cent, fuel 4.7 per cent, and supplies about 6 per cent. The remaining 5 per cent of the cost was distributed among the other items.

The total number of men engaged in the operation of the plant is thirty-four, of which five men are employed on each of the three shifts per day. Six men are employed for the greater part of their time during the day at the filter plant, the remainder of their time being divided among other divisions of the water department. The remaining thirteen men compose the day force, and include the superintendent, laboratory force, the electrician with his assistants, machinist with helper, and the janitor. As it is not probable that any material increase will be required in this force with an increase in the consumption of water, the relative cost of purification per million gallons will likely decrease as the demand upon the plant for filtered water increases.

The cost of cleaning the three coagulation basins in November, 1908, is shown by the following table:

	Basin No. 1	Basin No. 2	Basin No. 3
Cost of labor for removing mud	$24.07	$25.63	$10.00
Cost of labor for operating flushing pumps	6.44	4.76	2.52
Cost of power for operating flushing pumps	17.71	13.09	6.93
Cost of water used in flushing	4.28	3.16	1.67
Total Cost	$52.50	$46.64	$21.12

The total cost of cleaning these three basins amounted to $120.26. The inlet conduit of basin No. 1 was not cleaned. All the other inlet and outlet conduits, however, were cleaned.

MAIN PUMPING STATION.

As has been stated, one of the high service pumping engines installed at this station was started delivering water to the hilltops on January 2, 1907, while the erection of the other pumping engines was proceeding and this service has continued, with the exception of a few interruptions early in January, 1907, supplying all the water for the territory heretofore supplied by the Eden Park, Hunt Street, Linwood, and Cumminsville pumping stations.

On June 16, 1907, the low service pumping engines at this station were placed in regular commission, and, excepting the period from July 13 to 25, have supplied all the water for the intermediate service, by delivering the same at first through Eden Park Reservoirs, and since September 25, 1907, by delivering the water direct to the consumers without first sending the same through these reservoirs, which method of

delivery increased the pressure in the business district by about sixteen pounds, with four pounds less pressure at the pumps. At this time the division between the old low and intermediate services of the city was abolished, and the use of the Third Street Reservoirs discontinued. All of the territory below the hilltops has since been served in common, which has very greatly increased the pressure throughout the former low service district along the river front.

Under an agreement with the contractors for the pumping machinery at this station, similar to that had at the river station, the pumping engines were operated until August 1, 1907, under the direction of their Superintendent of Erection and by engineers, oilers, and some firemen selected by him for that purpose, which arrangement allowed the contractors to proceed with the erection of all the pumping machinery without interference with either class of work. The balance of the employees, and since August 1, 1907, all of the employees engaged in the operation of the machinery at this station have been on the pay-roll of your Board.

The total number of regular employees engaged here does not exceed fifty-five as against 205 men heretofore employed at the several pumping stations which have been supplanted by the work of this station.

During 1908 the total amount of water pumped at this station, which represents the total amount supplied to all consumers, was 15,275,920,137 gallons, or a total daily average of 41,737,487 gallons, of which 12,267,453 gallons were sent to the hilltops and 29,470,034 gallons went to the territory below the hilltops, a small portion of which was repumped at the Western Hills Station. In computing the quantities here given, 1.6 per cent is allowed for slippage, which was determined by a careful measurement in the clear-water basin, after making due allowance for leakage in the tunnel and for other losses at the station.

The total average cost per million gallons pumped at this station, which covers both services, was $6.68, which included all labor, fuel, light, supplies, maintenance, and repairs.

The boiler plant and its auxiliaries at this station have never been of a character equal to that of the pumping engines, either in capacity or workmanship. This was most effectively demonstrated during the test trials of the several pumping engines, when, notwithstanding every effort on the part of the contractors and their experts to place the boilers in the very best conditions, they were not able to develop a higher average duty with either the high or the low service pumping engines than about 153 and 142 million foot pounds respectively for every 100 pounds of coal consumed in the boiler furnaces. Moreover, the furnaces did not prove to be smokeless, but furnished

ample reason for numerous complaints by residents on the hilltops. In fact, the contractors were obliged to overhaul and replace a large amount of work and material before this part of their work was in any way acceptable. At this time they have not yet completed all of the work of replacement or of bringing the furnaces up to the requirements of the specifications regarding the elimination of smoke.

WESTERN HILLS STATION.

One of the two Snow pumping engines was started on April 15, 1907, supplying the elevated territory of Fairmount, and the Westwood Pumping Station, and in part the Price Hill territory until December 24, 1907, after which time the entire supply for Price Hill was delivered from this station, and the Mt. Hope Pumping Station was permanently closed. Since October 3 the supply to Price Hill has been delivered principally through the new 16-inch main laid on Quebec Road. Until August 1, 1907, the Snow pumps were operated under the direction of the contractors and by engineers in their employ under an agreement similar to that had at the other stations. Since August 1 all of the men engaged at this station have been employees of your Board.

Since October 20, 1908, one or the other of the two Laidlaw-Dunn pumps, removed from the old Linwood Pumping Station, has been supplying the Westwood territory, and Westwood Station, the last of the old pumping stations, was shortly thereafter permanently closed. The addition of the Westwood service to this station has and will not require any addition in the number of men regularly employed, consisting altogether of three engineers, three firemen, and one janitor.

Notwithstanding this minimum number of men employed to operate this station, the cost per million gallons pumped to each of the two services is quite high because of the limited territory and amount supplied.

The total cost of operation, maintenance and repairs of the new works for the year 1908, which included the filtration plant and all supplies of every kind, as well as lighting, was $245,749.97, or $16.09 per million gallons of water delivered to the consumers by the pumps at the Main Pumping Station, which included also all the cost of repumping. This represents, when compared with the cost of operating and maintaining the old pumping stations during the year 1906, a saving of $241,450.08.

On August 10, 1906, the maintenance and control of a large part of the betterment of the distribution system, which had been completed and put into service, was turned over to the Board of Public Service. On March 29, 1907, and again on January 3, 1908, an additional number of mains laid by your Board were transferred to the Water Department, the balance of the mains laid being turned over to that department on Novem-

ber 30, 1908. All the tracings showing the location and sizes of these mains, with their valves, special castings, and other information have been filed with the City Water Department.

As the period of probation and of maintaining the street surfaces on a number of the pipe-laying contracts were not to expire until 1910 and later, and as your Board has been anxious to close up all contracts, the Board of Public Service was requested to have the work of restoring the street surfaces under these contracts examined and ascertain whether they are warranted in accepting the work at this time and of releasing the contractors of their contract guarantee. Upon a favorable report by said Board, submitted at different times, finally accepting all of the work of the unexpired pipe-laying contracts, the retained percentages with interest were paid.

The contracts which, at the closing of this report have not been entirely completed, terminated, or finally adjusted are Numbers 26, 28, 49, 57, 69, 77, 117, 118, and 125. The last three contracts are for furnishing coal and for chemicals for the filter plant, and are connected with the operation of the Works. These will not expire until all the material as needed has been delivered. Contracts Numbers 26 and 28 are for the pumping machinery at the River and Main Pumping Stations. Both the Camden Iron Works and the Holly Manufacturing Co. have filed claims to the amount of $86,766.30 and $89,127.06 respectively in excess of the amounts which are covered by the estimates and bonus to be allowed. These claims may delay for some time the final adjustment of these contracts. The painting of the pumping engines under both contracts is now, after considerable delay, proceeding quite satisfactorily, and will likely be completed within the next sixty days. The work of replacing the valves in the lines of steam pipes at the Main Pumping Station, of improving the boiler furnaces, and of correcting other defects, is progressing, and it is hoped will soon be completed.

Contract No. 49 covers the work of constructing the settling reservoirs, and aside from grading and sloping some small areas and of some sodding and seeding, the same is practically completed. The work is to be done as soon as the weather will permit.

Contract No. 57 covered the lining of these reservoirs. This work is also completed, and final payment awaiting the adjustment of certain claims on the part of the city.

The final adjustment of Contract No. 69 depends upon the issue of certain suits on claims filed by various parties who furnished material to the contractor.

Final payment on Contract No. 77 will be made as soon as certain repairs to the roof of the filter and head houses have been made.

All of these contracts will most likely be closed and finally adjusted within the next few months, making it possible for your Board to then, in accordance with the provisions of the act under which this work has been constructed, to surrender and turn over to the Board of Public Service of the City of Cincinnati all of the new Water Works, together with the control, operation, and management of the same, which, when accompanied by a final statement of the disposition of the funds entrusted to your care, will complete the duties of your Board, which have not only consisted in providing Cincinnati with a Water Works which furnishes its citizens with an abundant supply of pure and wholesome water, but in overcoming the many prejudices and obstacles which were encountered during its period of construction.

The records of this office regarding all this work, consisting of the plans, specifications, contracts, correspondences, reports of engineers and inspectors, copies of all estimates, vouchers, pay-rolls, and other data, have been properly arranged, indexed, and filed in suitable drawers and cases and stored in a separate room on the second floor of the vestibule wing of the Main Pumping Station for future reference or service.

In concluding this report it is proper to refer to the losses this department has suffered by death since its first organization. In the death, on November 6, 1904, after a protracted illness, of L. F. G. Bouscaren, your Board and this department sustained a loss of an exceptionally able, conscientious, and industrious Chief Engineer, who was unselfish, unassuming, and ever courteous toward his assistant and co-laborers.

In the sudden passing away on January 18, 1908, of Chas. Hermany, your Board lost the service of one whose long experience in designing and constructing Water Works made him a safe adviser and counsellor.

Among others, the following died while employed in this department: On April 18, 1904, J. F. Wilson, who was its competent and careful Chief Clerk; on May 14, 1901, Alfred Petry, its first Resident Engineer; on July 12, 1906, Simon Vivian, its capable Mechanical Engineer and Draughtsman; on June 23, 1904, George T. Smith, Assistant Engineer; on July 13, 1902, Jos. H. Barker, Field Clerk, and on May 13, 1905, Ora Parker, one of the principal Inspectors.

In conclusion the writer wishes to acknowledge the faithful and efficient services of all the employees of this department, but owing to their large number it is impossible to make personal mention of all; it is, however, but justice to make special reference to the able services of C. N. Miller, Alfred Petry, John A. Hiller, E. G. Manahan, and W. C. Jewett, Assistant and Resident Engineers, to whose zeal and fidelity to a large

extent is due the success of the work, and to the effective services of S. G. Pollard, Chief Mechanical Engineer, and J. W. Ellms, Superintendent of the filter plant, to whose ability and loyal co-operation in a great measure may be attributed the very efficient, economic, and successful operation of the new Works.

The undersigned herewith expresses his sincere thanks and appreciation to your Board for its uniform confidence and support and the very pleasant associations that have always existed between your Board and yours

Respectfully,

G. H. BENZENBERG,

Chief Engineer.

APPENDICES

APPENDIX A

List of contracts entered into by the Board of Trustees "Commissioners of Waterworks," in connection with the improvement of the Water Supply of Cincinnati, Ohio, and with the operation of the New Works up to December 31, 1908.

APPENDIX A — CONTRACTS

Contract Number	CHARACTER OF WORK	Number Bidders	Contract Price	Engineer's Estimate Cost of Work
1	Experimental Purification Plant — Laboratory and office building and shed over filters	8	$1,528 00	$2,050 00
2	Experimental Purification Plant — Four steel settling tanks, 25 feet diameter, 34 feet high	14	4,544 00	7,500 00
3	Experimental Purification Plant — Fifteen wooden filter tanks	2	1,230 00	1,500 00
4	Experimental Purification Plant — Pile foundations	4	2,448 00	5,000 00
5	Pumping machinery, boilers, and traveling crane, Eastern or River Pumping Station	8	514,400 00	600,000 00
6	Intake pier, tunnel and pump pit, Eastern or River Pumping Station	9	440,699 25	490,876 00
7	Sluice gates for intake pier	9	8,079 00	10,250 00
8	Grading of grounds, roads, and river bank, revetment of slopes and excavation of clear well, California	11	105,399 08	143,564 90
9	Foundations and masonry of railroad viaduct across the valley of Lick Run	7	5,219 00	7,220 50
10	Construction of railroad track and the delivery of track material	3	7,377 00	6,104 00
11	Superstructure of a steel railroad viaduct across the valley of Lick Run	13	24,900 00	28,092 50
12	Construction of Settling reservoirs and laying of pump mains from the Eastern Pumping Station	9	1,171,743 50	1,263,702 00
13	Grading, masonry, drains, macadamizing, and revetment of slopes of a part of the Columbia and New Richmond Turnpike, of the Little Miami River Bank, and of the railroad branch	5	35,476 25	38,457 00
14	Purchase and removal of the tanks, buildings, tools and material, for the experimental water purification plant near Eden-Park reservoir	3	Amount paid Board $1,020 00	No estimate
15	Purchase and removal of building, plank walk, sand-hoppers, etc., experimental station, Eden Park	2	Amount paid Board $364 00	No estimate
16	Protection of the Little Miami river bank, with piling, sheet piling, and loose rock	6	9,444 22	10,793 33
17	Manufacture, furnishing, and delivery of cast-iron pipe and special castings for the settling reservoirs	3	37,737 00	37,766 00
18	Grading of grounds and roads, construction of drains, excavation of basins, and revetment of slopes	5	139,267 50	140,247 00
19	Superstructure of a steel truss bridge to connect the intake pier with the Kentucky shore of the Ohio River	17	19,300 00	20,157 50
20	Construction of a tunnel and shafts for supplying water to the Western or Main Pumping Station	7	308,164 80	337,974 75
21	Construction of 16-ft. arch culvert and embankment	3	11,264 70	11,719 00
22	Deep-well pump for the intake tunnel	2	11,986 00	10,000 00
23	Construction of a tunnel extension and shafts for supplying water to the Western Pumping Station	4	659,230 00	662,943 00

Contract Number	CONTRACTOR	Date of Contract	Date of Final Payment	Total Payments Made Including Supplementary Contracts
1	Jos. C. Stein, Cincinnati	Dec. 14, 1897	Mar. 2, 1898	$1,528 00
2	Stacey Mfg. Co., Cincinnati	Dec. 14, 1897	Mar. 31, 1898	4,544 00
3	Hauser-Brenner-Fath Co., Cincinnati	Dec. 14, 1897	Mar. 31, 1898	1,230 00
4	Glandorf & Farrel, Cincinnati	Dec. 21, 1897	Mar. 2, 1898	2,461 40
5	Lane & Bodley Co., Cincinnati	Jan. 4, 1898	Annulled Jan. 16, 1900	1,166 79
6	F. H. Kirchner & Co., Cincinnati	May 10, 1898	May 6, 1902	470,833 22
7	Vulcan Iron Works, Chicago	Aug. 12, 1898	Aug. 25, 1899	9,035 00
8	David Folz Asphalt Paving Co., Cincinnati	Sep. 20, 1898	April 3, 1900	15,883 60
9	Theo. Koenig, Cincinnati	Sep. 27, 1898	April 28, 1899	4,884 67
10	Edward W. White, Cincinnati	Nov. 1, 1898	June 26, 1900	7,066 68
11	Fort Pitt Bridge Works, Pittsburg	Nov. 25, 1898	Nov. 24, 1899	25,215 00
12	Aug. J. Henkel, Cincinnati	May 16, 1899	Annulled June 24, 1904	283,014 75
13	E. C. Boyce, Cincinnati	June 2, 1899	Dec. 26, 1900	29,096 69
14	L. Schreiber & Sons Co., Cincinnati	June 13, 1899	No payments	
15	Charles H. Glandorf, Cincinnati	June 16, 1899	No payments	
16	Thomas Maloney, Cincinnati	Sep. 15, 1899	June 15, 1900	9,481 81
17	U. S. Cast-Iron Pipe and Foundry Co., Chicago	Mar. 9, 1900	May 7, 1901	33,648 59
18	Aug. J. Henkel, Cincinnati	Mar. 28, 1900	Aug. 29, 1902	144,860 76
19	Brackett Bridge Co., Cincinnati	May 11, 1900	Dec. 27, 1901	19,300 00
20	W. J. Gawne Co., Cleveland	July 16, 1900	May 19, 1905	363,300 80
21	F. H. Kirchner Co., Cincinnati	Aug. 14, 1900	Nov. 9, 1900	11,386 61
22	Hendrick Mfg. Co., Carbondale, Pa	Aug. 20, 1900	Feb. 12, 1904	12,511 37
23	W. J. Gawne Co., Cleveland	Oct. 19, 1900	May 19, 1905	648,012 62

Contract Number	CHARACTER OF WORK	Number Bidders	Contract Price	Engineer's Estimate Cost of Work
24	Furnishing and delivery of cast-iron pipe and special castings for the settling reservoirs and for the pump mains from Eastern Pumping station	2	$175,370 00	$155,784 00
25	Extension of steel shell of the pump-pit shaft for the Eastern Pumping Station	1	3,200 00	2,730 00
26	Pumping machinery, boiler, traveling crane, Eastern Pumping Station	4	817,000 00	----------
27	Water valves, sluice gates, and mud valves for settling reservoirs and pump main from Eastern Pumping Station	6	37,711 00	57,003 00
28	Construction, delivery, and erection of pumping machinery for Western Pumping Station	5	813,400 00	1,000.000 00
29	One semi-portable steam boiler, with all necessary adjuncts and fittings	1	1,330 00	1,500 00
30	Cast-iron pipe and special castings for the Western Pumping Station	1	23,155 14	17,052 00
31	Construction of house over intake pier at Eastern Pumping Station, near California, O	4	12,400 00	11,600 00
32	Grading of grounds and revetment of slope for the construction of pump pit of the Western Pumping Station	7	170,527 50	197,275 00
33	Buildings, foundations, and drains for the Eastern Pumping Station	6	183,230 75	172,104 85
34	Construction of chimney for the Eastern Pumping Station	2	14,950 00	13,350 00
35	Construction of buildings for the Western Pumping Station	5	379,635 20	359,268 10
36	Construction of coal-storage houses for Eastern and Western Pumping Stations	5	193,600 00	220,500 00
37	Extension of protection of the Little Miami River bank	3	10,643 30	12,501 50
38	Furnishing and delivering iron castings for the counterbalance weight for the caisson of the Eastern Pumping Station	10	72,870 00	84,000 00
39	Furnishing and erecting the steam-heating appliances for the buildings of the Eastern Pumping Station	5	2,380 00	2,200 00
40	Furnishing and delivering cast-iron pipes and special castings for the betterment of the water distribution system of the City of Cincinnati	2	421,070 00	409,550 00
41	Manufacturing, furnishing and delivering water valves and air valves for the betterment of the water distribution system of the City of Cincinnati	7	19,795 00	24,817 00
42	Laying cast-iron pipe, special castings and valves for the extension and betterment of the water distribution system on Observatory Avenue	4	1,833 50	2,250 00
43	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system on Madison Avenue	4	3,972 50	4,950 00
44	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system on Woodburn Avenue	3	9,128 00	9,650 00

ON IMPROVEMENTS—Continued.

Contract Number	CONTRACTOR	Date of Contract	Date of Final Payment	Total Payments Made Including Supplementary Contracts
24	U. S. Cast-Iron Pipe and Foundry Co., Chicago	Dec. 11, 1900	May 8, 1903	$179,558 98
25	Variety Iron Works Co., Cleveland	Jan. 22, 1901	May 28, 1901	3,053 00
26	Camden Iron Works, Camden, N. J	Feb. 5, 1901	Work not Completed	*694,506 45
27	Coffin Valve Co., Boston	Mar. 22, 1901	Mar. 13, 1903	40,235 50
28	Holly Mfg. Co., Lockport, N. Y	July 17, 1901	Work not Completed	*756,003 50
29	New Jersey Foundry and Machine Co., New York	Nov. 29, 1901	Feb. 25, 1902	1,330 00
30	U. S. Cast-Iron Pipe and Foundry Co., Chicago	April 4, 1902	Nov. 4, 1903	21,564 91
31	Isaac Graveson, Cincinnati	April 8, 1902	Nov. 15, 1904	12,400 00
32	The Western Construction Co., Indianapolis	April 22, 1902	Nov. 24, 1903	181,321 93
33	U. S. Construction Co., Milwaukee	July 29, 1902	Aug. 9, 1904	190,068 74
34	U. S. Construction Co., Milwaukee	July 29, 1902	Nov. 4, 1903	14,950 00
35	U. S. Construction Co., Milwaukee	Mar. 6, 1903	Oct. 4, 1907	390,906 63
36	Charles L. Strobel, Chicago	Mar. 31, 1903	April 18, 1905	199,403 00
37	Thos. Maloney, Cincinnati	Dec. 28, 1903	Sep. 15, 1905	19,481 49
38	Bollman-Wilson Foundry Co., Cincinnati	Jan. 15, 1904	April 8, 1904	71,368 79
39	Thos. J. Nichols & Co., Cincinnati	Jan. 29, 1904	June 16, 1905	2,380 00
40	U. S. Cast-Iron Pipe and Foundry Co., Chicago	July 26, 1904	Jan. 24, 1908	424,955 43
41	Coffin Valve Co., Boston	July 20, 1904	Dec. 15, 1905	26,036 80
42	Glazier & McLane, Newport, Ky	Aug. 9, 1904	June 9, 1905	1,848 05
43	Frank Burns, Cincinnati	Aug. 5, 1904	April 21, 1905	4,199 92
44	Frank H. Kirchner, Cincinnati	Aug. 5, 1904	May 23, 1905	10,374 30

*Payments to March 1, 1909.

Contract Number	CHARACTER OF WORK	Number Bidders	Contract Price	Engineer's Estimate Cost of Work
45	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system on Burnet Avenue	4	$17,039 50	$27,177 00
46	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system on Forest Avenue	8	11,531 50	18,034 00
47	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system on Hackberry Street and Madison Road	4	6,676 50	11,064 00
48	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system on Woolper Avenue, McAlpin Avenue and Lafayette Avenue	6	9,819 00	16,164 00
49	Completing the construction of settling reservoirs and the laying of pump mains	3	719,821 25	723,153 00
50	Furnishing and delivering cast-iron pipe and special castings for the coagulating basins, filters, and the clear-water reservoir near the village of California, and for the pump mains from the Western Pumping Station	1	417,566 20	421,800 00
51	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system on Paddack Road	9	3,186 60	3,785 00
52	Laying 6-, 8-, 10-, and 12-inch cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system	2	10,175 00	8,445 00
53	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system on Reading Road	6	9,428 50	11,225 00
54	Pumping machinery for Western Hills Pumping Station	9	33,600 00	38,000 00
55	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system on Cutter, Wade and Faulkner streets	4	15,977 30	25,575 00
56	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the Water distribution system on Western, McLean, and Spring Grove Avenues, and Draper Street	3	17,946 00	22,350 00
57	Completing the construction of settling reservoirs and the laying of pump mains (item 13 of contract No. 12 for asphalt, burlap and brick revetment)	3	298,517 60	361,110 00
58	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system on Eggleston Ave. and Ninth St.	4	44,742 00	39,960 00
59	Manufacturing, furnishing, and delivering sluice valves, and gate valves, for the filtration plant, and for the mains from the Western Pumping Station	3	53,696 00	54,400 00
60	Manufacturing, furnishing, and delivering gate valves, and mud valves for filtration plant	3	74,157 00	98,100 00

ON IMPROVEMENTS—Continued.

Contract Number	CONTRACTOR	Date of Contract	Date of Final Payment	Total Payments Made Including Supplementary Contracts
45	Keeling & Ridge Co. Pittsburg	Oct. 11, 1904	July 21, 1905	$15,916 39
46	Guy M. Gest, Cincinnati,	Oct. 11, 1904	Sept. 5, 1905	9,473 33
47	Frank H. Kirchner, Cincinnati	Oct. 11, 1904	May 26, 1905	6,427 70
48	Frank H. Kirchner, Cincinnati	Oct. 11, 1904	Sept. 8, 1905	10,403 68
49	Keeling & Ridge Co., and Mercantile Trust Co., Assignee, Pittsburg	Oct. 11, 1904	Work not Completed	*731,003 66
50	U. S. Cast-Iron Pipe and Foundry Co., Chicago	April 4, 1905	Jan. 24, 1908	439,159 24
51	Thos. Maloney, Cincinnati	May 9, 1905	Feb. 13, 1906	3,312 89
52	Frank Burns, Cincinnati	May 16, 1905	July 3, 1906	9,148 58
53	Frank Burns, Cincinnati	June 13, 1905	Feb. 23, 1906	9,524 15
54	Snow Steam Pump Works, Buffalo	June 20, 1905	July 31, 1908	35,145 00
55	Guy M. Gest, Cincinnati	June 23, 1905	Sept. 4, 1906	17,066 26
56	Guy M. Gest, Cincinnati	June 23, 1905	Aug. 17, 1906	19,937 79
57	Kirchner Construction Co., Cincinnati	July 25, 1905	Work not Completed	*248,251 68
58	Keeling & Ridge Co., Cincinnati	Aug. 11, 1905	July 23, 1907	51,363 43
59	Coffin Valve Co., Boston	Aug. 15, 1905	June 2, 1908	48,381 30
60	Fairbanks Co., New York	Aug. 15, 1905	July 14, 1908	73,197 23

*Payments to March 1, 1909.

Contract Number	CHARACTER OF WORK	Number Bidders	Contract Price	Engineer's Estimate Cost of Work
61	Unloading, hauling and delivering cast-iron pipe, special castings, and valves from the various railway yards to the different streets as specified	1	$16,251 50	$16,500 00
62	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system on Carthage Pike and Mitchell Avenue	7	8,695 00	9,340 00
63	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system on Ludlow Ave. and Dodsworth Avenue	3	4,799 60	5,200 00
64	Laying cast-iron pipe, special castings, and valves under and across Mill Creek for the extension and betterment of the water distribution system on Queen City Avenue and Liberty Street and Dodsworth Avenue	2	9,981 75	8,300 00
65	Furnishing and delivering filter sand and gravel for the filtration plant	4	9,120 00	14,800 00
66	Construction of filters, coagulation basins and clear-water reservoir, with valve chambers, pipe lines, and miscellaneous work in connection therewith	5	487,565 75	539,500 00
67	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system on Eastern Avenue, Columbia Avenue, and Humboldt Ave.	4	42,705 00	42,885 00
68	Manufacturing, furnishing, and delivering steel pipe and appurtenances for the filtration plant and settling reservoirs	3	42,132 00	39,200 00
69	Construction of buildings, foundations, and other work for the Western Hills Pumping Station east of Shadwell St. on the north side of Queen City Avenue	4	51,920 05	46,200 00
70	Construction, delivery, and erection of coal-hoisting machinery and appurtenances, and for four movable steel aprons, and twelve two-ton steel coal dump-cars for the Eastern or River Pumping Station, near California, O., and for the Western or Main Pumping Station, Cincinnati, O	2	13,309 00	11,800 00
71	Furnishing and delivering 3½-inch special castings for the filtration plant	3	4,600 00	4,600 00
72	Construction, delivery, and erection of the electric generating machinery for the Eastern Pumping Station	7	28,742 55	44,400 00
73	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system on Eastern Avenue, from the Western Pumping Station on Eastern Avenue to Broad Street	7	60,399 50	71,200 00
74	Unloading, hauling, and delivering cast-iron pipe, special castings, and valves from the various railway yards to the different streets as specified	1	14,280 00	14,180 00
75	Laying lines of 6-, 8-, 10-, and 12-inch cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system	4	9,435 00	11,225 00
76	Laying cast-iron pipe, special castings, and valves for the extension and betterment of the water distribution system on Eastern Avenue from Broad Street to Third Street, and on Third Street from Eastern Avenue to Martin Street	7	56,400 00	57,700 00

ON IMPROVEMENTS—Continued.

Contract Number	CONTRACTOR	Date of Contract	Date of Final Payment	Total Payments Made Including Supplementary Contracts
61	George Reichel, Cincinnati	Sep. 12, 1905	Jan. 28, 1908	$13,892 60
62	Malarky & Underhill, St. Bernard, O	Sep. 22, 1905	Aug. 7, 1906	8,769 88
63	Heffner, Gibney & Heffner, Celina, O	Oct. 27, 1905	Jan. 4, 1907	4,730 40
64	Thos. Maloney, Cincinnati	Oct. 27, 1905	Aug. 16, 1907	11,106 42
65	J. R. Ware & Son, Cincinnati	Nov. 3, 1905	Oct. 15, 1907	8,482 67
66	Kirchner Construction Co., Cincinnati	Oct. 31, 1905	Feb. 2, 1909	494,265 04
67	Keeling & Ridge Co., Cincinnati	Nov. 16, 1905	July 23, 1907	42,804 23
68	Riter-Conley Mfg. Co., Pittsburg	Nov. 28, 1905	April 12, 1907	42,132 00
69	Charles J. Close, Columbus, O	Feb. 13, 1906	Contractor declared in default April 12, 1907 Work completed by Trustees.	*52,693 84
70	I. & E. Greenwald Co., Cincinnati	Mar. 2, 1906	April 5, 1907	13,309 00
71	U. S. Cast-Iron Pipe and Foundry Co., Chicago	Mar. 6, 1906	Oct. 12, 1906	4,827 42
72	Dravo, Doyle & Co., Pittsburg	Mar. 16, 1906	May 22, 1908	30,353 65
73	Kirchner Construction Co., Cincinnati	Mar. 30, 1906	Dec. 23, 1907	65,351 04
74	George Reichel, Cincinnati	April 6, 1906	Aug. 2, 1907	15,187 29
75	August Silk, Cincinnati	April 17, 1906	May 25, 1907	5,441 34
76	Kirchner Construction Co., Cincinnati	April 27, 1906	Jan. 21, 1908	75,741 00

*Payments to March 1, 1909.

Contract Number	CHARACTER OF WORK	Number Bidders	Contract Price	Engineer's Estimate Cost of Work
90	Furnishing and installing electric lighting and wiring of the pumping machinery and coal-sheds at the Main Pumping Station, Eastern Avenue	5	$1,180 00	$1,850 00
91	Furnishing and installing electric lighting and wiring around the filter plant, settling reservoirs, valve, shaft and other houses	5	10,247 00	10,500 00
92	Furnishing and installing electric lighting and wiring of the buildings and grounds at the Eastern Pumping Station and on the intake pier and the pumping engines at the Eastern Pumping Station, and for furnishing and constructing an electric conduit and cable from the Eastern Pumping Station to the filter-house at California, O	5	63,803 50	75,250 00
94	Laying cast-iron pipe, special castings and valves for the extension and betterment of the water distribution system on Madison Road from Observatory Ave. to Edwards Road	6	5,174 00	6,650 00
95	Laying cast-iron pipe, special castings and valves for the extension and betterment of the water distribution system on Langdon Avenue from Woodburn Avenue to Duck Creek Road, and on Duckcreek Road from Langdon Ave. to Fairview Avenue, and on Fairview and Ivy Avenues from Duckcreek Road to Madison Road	4	13,365 00	14,385 00
96	Furnishing and delivering one electric hoist of 2,000 pounds capacity in the shaft at the River Pumping Station, California, O	1	1,350 00	1,200 00
97	Furnishing all material and labor for completing valve chambers Nos. 1 and 3 on the water works grounds, California, O	1	2,023 00	1,700 00
98	Furnishing all materials and labor for laying a concrete floor in the pump pit of the River Pumping Station, California, O	2	1,900 00	1,700 00
99	Furnishing and delivering one electric storage battery locomotive on the tracks at the River Pumping Station, California, O	5	2,280 00	3,500 00
100	Furnishing and delivering twelve coal and six ash cars, f. o. b. cars on the tracks at the River Pumping Station, California, O., and fifteen coal and two ash cars, f. o. b. cars in Cincinnati, O	5	2,475 00	3,400 00
101	Laying cast-iron pipe, special castings and valves for the extension and betterment of the water distribution system on Mound Street between Van Horn Street and Ninth Street, Freeman Avenue from Kenner Street to Wade Street, and Hulbert Street and Freeman Avenue from Western Avenue to Findlay Street	3	4,153 00	4,250 00
102	Laying cast-iron pipe, special castings and valves for the extension and betterment of the water distribution system on Liberty Street from Faulkner Street to Mill Creek, and from Mill Creek to State Avenue	4	9,788 40	10,375 00
103	Laying cast-iron pipe, special castings and valves for the extension and betterment of the water distribution system on Grand Avenue from Glenway Avenue to Warsaw Avenue, on Warsaw Avenue from Grand Avenue to Hawthorne Avenue, and Price Avenue from Hawthorne Avenue to Elberon Avenue	4	2,532 50	2,450 00

ON IMPROVEMENTS—Continued.

Contract Number	CONTRACTOR	Date of Contract	Date of Final Payment	Total Payments Made Including Supplementary Contracts
90	A. S. Schulman, Cincinnati	Nov. 20, 1906	Nov. 15, 1907	$2,272 55
91	Beattie Electric Co., Cincinnati	Nov. 20, 1906	Jan. 15, 1908	10,247 00
92	Sackett Mine Supply Co., Columbus, O.	Nov. 27, 1906	June 30, 1908	63,803 50
94	August Silk, Cincinnati	April 23, 1907	Feb. 15, 1909	5,112 69
95	Douglas Plumbing and Heating Co., Cincinnati	April 28, 1907	Work not Completed	*12,866 23
96	Warner Elevator Mfg. Co., Cincinnati	May 15, 1907	Nov. 22, 1907	1,350 00
97	The L. Eid Concrete Steel Co., Cincinnati	May 15, 1907	Nov. 29, 1907	2,023 00
98	J. E. Gomien and C. W. Settle, Cincinnati	May 15, 1907	July 23, 1907	1,900 00
99	Westinghouse Electric Mfg. Co., Pittsburg	May 21, 1907	Jan. 24, 1908	2,280 00
100	Arthur Koppel Co., Chicago	June 14, 1907	April 21, 1908	2,117 82
101	August Silk, Cincinnati	June 14, 1907	Work not Completed	*3,962 55
102	August Silk, Cincinnati	June 14, 1907	Work not Completed	*10,604 88
103	Frank Burns, Cincinnati	Sept. 6, 1907	Feb. 15, 1909	2,752 41

*Payments to March 1, 1909.

APPENDIX A — CONTRACTS

Contract Number	CHARACTER OF WORK	Number Bidders	Contract Price	Engineer's Estimate Cost of Work
106	Laying an 8-inch water pipe, special castings, stop-valves, etc., at the River Pumping Station and at the Main Pumping Station	4	$1,983 25	$1,780 00
107	Furnishing and delivering track material at the River and Main Pumping Stations	4	3,476 95	4,300 00
108	Laying narrow-gauge track at the River Pumping Station	2	5,000 75	4,950 00
112	Furnishing and delivering cast-iron pipe and special castings for the water mains required for the betterment of the distribution system	2	2,685 00	2,550 00
113	Laying cast-iron pipe, special castings and valves in alley east of Western Hills Pumping Station, from said station to Harrison Ave. and on Harrison Ave., from said Alley to Seegar Street	9	915 00	1,400 00
114	Furnishing and delivering cast iron pipe and special castings for the water mains required for the extension and betterment of the distribution system	2	15,877 00	17,350 00
115	Laying cast iron pipe, special castings and valves, on Queen City Ave. from Shadwell Street to Quebec Road and on Quebec Road from Queen City Ave., to Glenway Ave.	11	9,145 50	9,930 00
116	Constructing a storehouse at the west end of the bridge approach to the intake pier	4	4,139 25	3,200 00
119	Constructing and delivering machine tools for the several pumping stations, the filter plant and the intake pier	19	4,446 70	4,835 00
120			1,102 00	1,200 00
121			799 50	1,125 00
122			1,864 00	2,200 00
123			2,427 00	2,870 00
124			735 00	770 00

ON IMPROVEMENTS — Continued.

Contract Number	CONTRACTOR	Date of Contract	Date of Final Payment	Total Payments Made Including Supplementary Contracts
106	Frank Burns, Cincinnati	Sept. 6, 1907	Nov. 15, 1907	$2,020 26
107	Cincinnati Frog and Switch Co., Cincinnati	Nov. 8, 1907	Feb. 21, 1908	3,582 32
108	Charles Underhill, Cincinnati	Nov. 8, 1907	Mar. 20, 1908	5,112 72
112	Dominick Pipe Co., Birmingham, Ala	April 28, 1908	June 30, 1908	2,336 11
113	Quill & Poos, Cincinnati, O	May 1, 1908	Feb. 15, 1909	898 25
114	U. S. Cast Iron Pipe & Foundry Co., Chicago, Ill	June 12, 1908	Aug. 14, 1908	16,255 72
115	Evan Evans, Cincinnati, O	July 7, 1908	Feb. 15, 1909	9,973 11
116	Jos. C. Stein, Cincinnati, O	Aug. 21, 1908	Dec. 15, 1908	4,091 07
119	The E. A. Kinsey Co., Cincinnati, O	Oct. 13, 1908	Jan. 15, 1909	4,446 70
120	The American Tool Works Co., Cincinnati, O	Oct. 13, 1908	Jan. 15, 1909	1,045 00
121	The Queen City Supply Co., Cincinnati, O	Oct. 13, 1908	Jan. 15, 1909	937 50
122	The Fosdick Machine Tool Co., Cincinnati, O	Oct. 23, 1908	Jan. 15, 1909	1,884 00
123	The Motch & Merryweather Machinery Co., Cincinnati, O	Oct. 23, 1908	Work not Completed	*2,184 30
124	Manning, Maxwell & Moore, Cleveland, O	Oct. 23, 1908	Jan. 26, 1909	735 00

*Payments to March 1, 1909.

APPENDIX A — CONTRACTS

Contract Number	CHARACTER OF WORK	Number Bidders	Contract Price	Engineer's Estimate Cost of Work
80	Furnishing and delivering coal for the Eastern or River and the Western or Main Pumping Stations	1	$9,750 00	$10,500 00
93	Furnishing and delivering coal for the River and Main Pumping Stations	1	31,350 00	27,550 00
104	Furnishing and delivering crushed lime for the filtration plant	3	7,920 00	7,200 00
105	Furnishing and delivering sugar sulphate of iron for the filtration plant	1	13,200 00	11,250 00
109	Furnishing and delivering coal at the River and Main Pumping Stations	2	19,800 00	20,400 00
110	Furnishing and delivering coal for the River and Main Pumping Stations	2	20,375 00	20,625 00
111	Furnishing and delivering coal for the Western Hills Pumping Station	3	2,520 00	2,580 00
117	Furnishing and delivering crushed lime for the filtration plant	4	7,260 00	7,000 00
118	Furnishing and delivering sugar sulphate of iron for the filtration plant	1	21,600 00	19,000 00
125	Furnishing and delivering coal for the River and Main Pumping Stations	2	29,568 75	34,000 00

ON OPERATION.

Contract Number	CONTRACTOR	Date of Contract	Date of Final Payment	Total Payments Made Including Supplementary Contracts
80	Monongahela River Consolidated Coal & Coke Co., Cin'ti	June 29, 1906	Jan. 15, 1907	10,388 89
93	Monongahela River Consolidated Coal & Coke Co., Cin'ti	Mar. 12, 1907	Aug. 13, 1907	36,269 31
104	Moores-Coney Co., Cincinnati	Sept. 6, 1907	Oct. 13, 1908	6,353 08
105	American Steel and Wire Co., Chicago	Sept. 6, 1907	Oct. 13, 1908	19,835 01
109	Monongahela River Consolidated Coal & Coke Co., Cin'ti	Nov. 12, 1907	Jan. 14, 1908	21,417 29
110	Monongahela River Consolidated Coal & Coke Co., Cin'ti	Mar. 31, 1908	June 12, 1908	32,317 03
111	Fairmont Coal Co., Cincinnati, O.	April 24, 1908	Dec. 18, 1908	2,520 00
117	The Moores-Coney Co., Cincinnati, O.	Oct. 6, 1908	These contracts cover the delivery of material required for the operation of the works and will not be closed until a date subsequent to that of this report.	
118	The American Steel and Wire Co., Chicago, Ill.	Oct. 6, 1908		
125	The Cincinnati Gas Coke, Coal & Mining Co., Cincinnati	Oct. 30, 1908		

APPENDIX B

Report Upon the Best System of Purifying the Ohio River Water

CINCINNATI, OHIO, January 12, 1900.

BOARD OF TRUSTEES, "COMMISSIONERS OF WATER WORKS," CINCINNATI, OHIO:

Gentlemen — On November 28, 1899, the following resolution was passed by your Board:

"Resolved, That the Chief Engineer and his Associate Engineers be requested to prepare and submit to this Board the most feasible and economical method of purification and filtration of Ohio River water, coupled with the cost of construction and cost per million gallons of filtered water."

A full compliance with your instructions involves —

First — A decision as to the method or system to be adopted for purifying the Ohio River water at Cincinnati.

Second — The design of a plant suitable for the application of the method to be adopted; said design to be in accordance with the best practice, in harmony with local conditions, and of sufficient size to treat the city's supply.

Third — Careful estimates of the cost of construction and of the cost of operation of said plant.

The results of the investigations made in 1898 and 1899 at your Experimental Station, under the supervision of Mr. George W. Fuller, as given in his reports submitted to your Board on February 17 and on June 21, 1899, have enabled us to arrive at definite conclusions with regard to the system best suited for the purification of the Ohio River water at Cincinnati, when all the local conditions are taken into consideration. We are therefore prepared to report upon the first question formulated in your resolution. It is advisable that this question be determined as soon as practicable, in order to avoid delaying the execution of other parts of the work.

Considerable time will be required for the preparation of detail plans upon which correct estimates of cost can be made. In view of the fact that four years will probably be required for the construction of the reservoirs, while the filters can easily be built within two years time, their construction can be postponed another year without retarding the date when pure water can be delivered to the city. We would therefore respectfully suggest that ample time be allowed for the preparation of these plans.

The primary object of the investigations made by authority of your Board was to intelligently determine between the merits of the English and Mechanical filtering systems, as applied to the Ohio River water.

The English system, so called because it was first applied in England for the purification of the London water supply, is now largely and successfully used on the Continent of Europe, and has received a limited number of applications in this country, the most recent being the filters at Albany, N. Y., completed last year.

This system consists in the slow filtration through sand of water previously relieved by sedimentation in settling reservoirs of a large proportion of such solid matter as it holds in suspension. It was first devised as a clarifying process, but it is generally admitted now that the high degree of purification obtained is partly due to the active bacterial life which prevails in the deposit formed on

the surface of the filter-beds, and in the gelatinous films which coat the sand grains in the filters after a short period of operation. When the resistance to the passage of water through the surface deposit has increased to such an extent as to seriously diminish the output, this deposit and a thin layer of the underlying sand are removed by scraping. This procedure is renewed until the sand layer is reduced to the thickness of about one foot, when the original thickness is restored by the addition of pure sand.

Essential requisites for the successful operation of this system are:

First — The preliminary treatment of the water by sedimentation to reduce the amount of suspended matter below a certain limit, and to avoid too frequent scrapings.

Second — A low and regular rate of filtration, varying from two to four million gallons per acre per twenty-four hours.

Third —The avoidance of all disturbance in the sand layer or of its covering; such disturbance being invariably the cause of a deterioration in the quality of the effluent.

The Mechanical system, sometimes called the American system, from the fact that it originated and is mainly applied in America, was also devised purely as a process to clarify water used for manufacturing purposes. As now improved and used extensively for the purification of water supplies of towns and cities in this country, it accomplishes practically the same results as the English system when operated under proper management.

It consists of the rapid filtration of the water through a body of sand in a closed or open tank. When clogged by the accumulation of sediment the sand is washed by an injection of pure water in reverse direction. The impurities are carried away by the wash water, whilst the sand is thoroughly loosened by mechanical agitation.

A necessary feature of this system, when designed to remove the bacteria as well as earthy matter in suspension, is the use of a chemical reagent capable of producing a gelatinous precipitate which will arrest the bacteria on and near the surface of the sand layer and prevent their passage through the filters. Another essential condition is that the chemical used as a coagulant shall leave the effluent free from the presence of all objectionable substances. When the raw water is quite turbid its preliminary treatment by sedimentation is indispensable to secure satisfactory and economical results.

The rate of filtration in this system is fully forty times greater than in the English system.

In the English system purification is effected through mechanical and biological agencies, generally without the use of chemicals. The rate of filtration is slow; the operation of the filters is intermittent; and the sand is washed outside the filters. In the American system the operation is mainly mechanical; the use of a coagulant is imperative; the rate of filtration is rapid, the operation of the filters is continuous, excepting the short interruption incident to washing; and the sand is washed in the filters.

The results of the tests made at the experimental station of both systems, applied to the purification of the Ohio River water, under all the variety of conditions arising from the influences of the seasons and from differences in the construction and mode of operation of the filters, can be summarized as follows:

1 — As to the Character of the Ohio River Water.

The local water, taken from the pump mains of the Front Street Pumping Station, is characterized:

a — By the wide range in the amount of suspended matter it contains, varying from about one-tenth ton to ten tons, and averaging about one ton per million gallons.

b — By the great variation in the nature of the suspended matter and the size of the particles; a large proportion of which, at certain seasons, being exceedingly small.

c — By the stable nature of the organic matter present, and the comparative absence of organic matter adapted to the formation of gelatinous films upon the sand grains.

d — By the constant presence of *Bacillus coli communis* — a positive indication of contamination by sewage.

e — By the presence in the water at all times of alkaline compounds, the alkalinity varying from twenty to seventy, the average being forty-five parts per million.

II — As to the Effect of Sedimentation.

The percentage of impurities removed from the water by a period of three days subsidence was found to average:

For suspended matter	75 per cent.
For organic matter	45 "
For bacteria	75 "

III — As to the Applicability of the English System.

Experiments were made with fifteen filters constructed with Ohio River sand of three degrees of fineness, corresponding approximately to the sands of maximum, minimum, and average sizes used in European filters. Three thicknesses of sand layers were used, viz., one foot, three feet, and five feet — and the rate of filtration was made to vary from one and one-half to four million gallons per acre daily. The total available head for the operation of these filters was thirteen feet, of which four feet were positive (above the surface of the sand layers).

It was found —

a — That the filters built with the maximum depth of fine sand (five feet) and operated at the minimum rate of filtration (1.5 million gallons per acre daily) gave the best results.

b — That owing to the frequent absence in the water of such organic matter as serves to form gelatinous films around the sand grains and a gelatinous coating on top of the sand layer, these features, upon which the efficiency of the process largely depends, were often lacking.

c — That owing to the imperfect formation of the "Schmutzdecke," and to the presence in the water of large numbers of minute clay particles, measuring one 100,000th of an inch and less, these particles will pass into the sand layer, necessitating more frequent and deeper scraping, and shortening the life of the sand layers.

d — That negative head is not permissible, which means that the loss of head can not be carried beyond the depth of water above the sand without serious disturbance in the regime of the filters and deterioration in the quality of the effluent.

e — That owing to the presence in the water at certain seasons of various forms of animal life, the upper portion of the sand layer is subject at such times to irregular disturbances, which affect the quality of the effluent.

f — That the quantity of clay in the applied water which filters built within practical limits as to thickness of sand layers, and operated within practical limits as to rate of filtration, can remove continuously and economically in a satisfactory manner, is about fifty parts (.2 ton) per million gallons.

g — That in the absence of long-continued freshets in the river three days subsidence is adequate to allow the water to be satisfactorily clarified and purified by such filters and at reasonable cost; but that long-continued rises in the river will result in a turbid effluent, a diminution in the bacterial efficiency, and an abnormal expense in cleaning the sand layers.

The fact was thus established that to apply English filters successfully at Cincinnati it would be necessary at times of freshets to give the water further preparatory treatment in addition to that afforded by three days subsidence. A longer period of subsidence would not afford an economical

solution, because the percentages of suspended matter removed by successive equal periods of sedimentation diminish very rapidly, and settling reservoirs of very much larger capacity than is practical would be required to accomplish the desired result.

The treatment of the subsided water by a coagulant and by supplemental subsidence before it reaches the filters was more promising, and was tried on two filters constructed with fine sand in thirty-inch layers, and operated at rates varying from 2.6 to 5 million gallons per acre daily. It was found that a satisfactory effluent could be obtained at all times by this method, using an average of 1.5 grains of sulphate of alumina per gallon, and allowing a period of twenty-four hours for supplemental subsidence after the application of the coagulant. It was also found that the complete removal of hydrate of alumina by subsidence, before applying the water to the filters, was an essential requisite, to avoid the rapid clogging of the sand layer, and that the judgment required to determine when and how much chemical should be applied to the water rendered the successful operation of the modified English system much more difficult than that of the English system as usually applied without the use of coagulants. The period during which the application of this modified system would be required to treat the Ohio River water in a satisfactory manner was found to be about four and a-half months for the year 1898.

IV — As to the Applicability of the American System.

The experiments made by the Louisville Water Company, under the supervision of Mr. Fuller, have demonstrated the applicability of the American system to the purification of the Ohio River water at Louisville, where the water is practically the same as it is at Cincinnati, excepting that the amount of suspended matter is much larger at Louisville. It was, however, considered advisable to make parallel investigations here to determine —

a — The amount of chemical required for satisfactory purification of the water after subsidence of two or three days.

b — The most efficient period of coagulation and supplemental sedimentation after subsidence.

c — The most efficient sand layer, both as regards thickness of layers and size of sand grains.

d — The most advantageous rate of filtration.

A four-foot filter, equipped with a mechanical agitator, and charged at different times with sands of different degrees of fineness, was used for these investigations. The total head available was ten feet. The period of time covered by the operation of this filter extended from September 14, 1898, to January 25, 1899. Sulphate of alumina was used in these investigations. It is quite possible, however, as our knowledge of coagulating chemicals advances, that it might be found advantageous to substitute some other chemical for sulphate of alumina. Such substitution would not involve any essential changes in the purification plant.

It was found that the quantity of chemical required to purify the water satisfactorily varied from 0.75 to 4.0 grains per gallon, and averaged 1.6 grains per gallon; that at periods of freshet and of maximum turbidity of the subsided water the efficiency of the filter could be fully maintained by providing supplemental subsidence for a period not exceeding six hours, and that the operation of the filter could be better regulated by the application of the chemical at two points, viz., as the water enters the coagulating basin and just before it is delivered on the filter; that a layer of fine sand thirty inches thick gave the best results; and that the fine sand pumped from the bar opposite Coney Island was suitable for the purpose. The rate of filtration was made to vary during the experiments from 46 to 170 million gallons per acre daily. It was found that the most economical rate was 125 million gallons per acre daily, but that higher rates can safely be used to meet increased consumption. It

was found that the use of negative heads was permissible, provided that the section of greatest frictional resistance in the filter be made at the straining system; and that the most economical head was ten to twelve feet, according to the thickness of the sand layer and the size of the sand grains; that the average percentage of wash water required for satisfactory and economical operation was about five per cent; that the interval between washings would vary from eight to twenty-four hours, and average fifteen hours; that during four months of the year the water can be pumped direct to the filter and subsidence omitted; that no trace of the chemical used as a coagulant ever appeared in the effluent; that the increase in permanent hardness, and in the proportion of carbonic acid present in the effluent, resulting from the use of sulphate of alumina was so slight as to have no practical significance. The conclusion is that the American system of filtration is applicable to the satisfactory purification of Ohio River water at Cincinnati at all seasons.

A careful comparison of the cost of operation per million gallons is made by Mr. Fuller in his report between the modified English system and the American system, showing the latter to be the cheaper.

In the absence of definite plans, correct estimates can not be given now of the cost of plants for the application of the two systems to the purification of the city's supply, but from what has been done elsewhere we can safely say that a mechanical plant would cost much less than a modified English plant, especially if provisions were made to cover the filter beds. A factor which should also be taken into consideration in such comparisons is the extent of ground available for the construction of the plant. While the grounds now owned by the city are ample for the convenient establishment of a mechanical plant of sufficient capacity to treat ninety million gallons daily, they are hardly adequate for the construction of filter beds of one-half this capacity without very heavy expense for grading.

For the foregoing reasons we would respectfully recommend the adoption of the mechanical system of filtration for the treatment of the water supply of Cincinnati. In arriving at this conclusion we have purposely confined ourselves to the consideration of the only two systems of purification which have been widely applied elsewhere, and which are known to be applicable to the treatment of the Ohio River water, believing that your Board would not approve of any method which has not received the sanction of practice.

Respectfully,

G. BOUSCAREN,
G. H. BENZENBERG,
CHAS. HERMANY.

APPENDIX B—Continued

Containing brief extracts from the reports of Mr. G. W. Fuller, Chief Chemist and Bacteriologist, on the results of the investigations made at the Experimental Filter Plant from March 28, 1898, to April 25, 1899, for the purpose of obtaining reliable data as to the relative merits of various methods of purifying Ohio River water.

General Description of the Experimental Plant.

The experimental purification plant was located on city property below and adjoining the retaining wall of the Eden Park Reservoir, where it could receive from the force mains the river water on its way to the reservoir. It had a capacity of 100,000 gallons per day. In brief terms the plant included the following principal parts:

1 — Four steel tanks of an available capacity of 100,000 gallons each, to be used for the preliminary treatment of the river water by plain subsidence.

2 — Fifteen experimental filters of an area of 1-400 acre each, receiving the subsided water and representing different kinds of local sand, different thicknesses of sand layers, and different rates of filtration.

3 — An office and laboratory building of a temporary nature, equipped with necessary apparatus and supplies to allow an extended series of chemical and bacterial analyses to be made, according to the most approved methods, of the water before, during, and after its treatment by this system.

The appurtenances of this plant included the necessary valves, meters, gauges, and other devices and tools for its operation and for a careful record thereof.

Practically without exception, all of the filtered water was discharged into the low-service main in Third Street.

On August 1, 1898, seven of the original filters were permanently stopped and the tanks emptied of the filtering materials. Two new filters, constructed in old tanks, were placed in operation on August 8, to be used in conjunction with a coagulating and subsiding basin, the latter having a capacity of about ten hours normal flow of water for these filters. At times of muddy water in the river, the plain subsided water was given a supplementary clarification before its application to the filters, with the aid of a coagulant and this extra subsidence. When the river water was fairly clear, no coagulant was used with this modified system.

During August a study was made of the best source from which to secure satisfactory filtering sand from the bars in the Ohio River, near the new works at California. To determine whether or not it would be advisable to wash the sand before its placement in a filter, two new filters, constructed in old tanks, were placed in operation on September 1.

During September all of the original experimental filters were stopped, except the most efficient one, in order to use the subsided water in the operation of a small American (mechanical) filter provided with coagulating basins. The object of these tests (beginning September 14) was to obtain directly comparable data with those from the August modification as to the most practicable method of using coagulants in connection with the treatment of plain subsided water.

A number of small modifications were made from time to time, in the study of special problems, related chiefly to washing the sand and to the coagulation of the water under different conditions.

On March 28, 1898, the plant was placed in regular operation, the subsiding tanks having been filled with river water prior to this date in order to supply the filters with subsided water from the outset. From this date the plant as a whole was kept in continuous operation, with no interruption of importance until the close of the tests on January 25, 1899.

To determine the character of the water before and after purification, and thereby the efficiency of the methods under consideration, 1,205 samples of water were analyzed chemically and 9,855 samples bacterially. In addition to this, the weight of suspended matters was determined in 561 special samples. The operation of the subsiding tanks was planned to suit the capacity of the filter plant, and the general method, starting with the tanks empty, was as follows:

Filling — Each tank was filled from below through a six-inch pipe supplying the river water under about forty-eight feed head when the tank was empty. This operation required from 3.5 to 4.5 hours, filling to a depth of thirty-three feet, the variation in the rate of pumping at the Front Street Pumping Station having been apparently the controlling feature in the rate of filling. The lowest point of discharge (side outlets) in these tanks was three feet above the bottom, and the depth required for 100,000 gallons was 26.8 feet, making a total depth of 29.8 feet. In order to maintain more pressure at the end of the drawing, it was originally planned to fill the tanks to thirty-three feet, and thus have 3.2 feet of pressure at the end of drawing.

Quiescent Subsidence — As soon as the tank was full all valves were closed, and the water was allowed to remain in a quiescent condition until it was necessary to begin drawing. This period was planned to be 2.5 days.

Drawing — Each tank was used in turn to supply the filters for twenty-four hours. As has been described, there were provided three outlet connections on each tank, placed at three, thirteen, and twenty-three feet, respectively, from the bottom of the tank. These valves were used in order, the top valve being first opened, and the water allowed to drain until it stood about one foot above the opening, when the second valve was opened. In a corresponding manner the third valve was opened. By this procedure the water was drawn from the tank in sections about ten feet deep at a maximum. This period of twenty-four hours gave an average additional subsidence of twelve hours for each lot, making the normal total period three days, or seventy-two hours.

Draining — It was originally intended to drain out the water left in each tank, in order to keep the evidence upon each tankful of water as clearly defined as practicable.

Cleaning — Each tank was to be cleaned by flushing before refilling, in order to avoid complications from disturbances of the accumulated sediment by the filling from below.

Refilling — The operation of filling was the same as that of refilling, as originally planned, each tank to be drained and cleaned after using.

Removal of Suspended Matter in the Subsiding Tanks After Subsidence for Two to Three Days.

Concerning the relative degrees of clarification of the water at different depths in the subsiding tanks, it may be said that except for a thin stratum at the top and another at the bottom of the tank, there was very little difference found in the grades of water examined with reference to this point.

The upper stratum of water, somewhat less than six inches thick, and the lowest six inches of water, were unusually clear and unusually turbid, respectively; but beween these strata the water was found in all cases to be uniform, practically speaking, though showing a slight tendency to increase toward the bottom in the amount of suspended matters. This is clearly seen from the following table, where averages of several observations are presented:

SUSPENDED MATTER IN OHIO RIVER WATER AFTER THREE DAYS SUBSIDENCE.

Distance from Surface	Suspended Matter	Percentage Removal
0.25 feet	137 parts per million	78.8
3.00 "	190 " "	70.3
8.00 "	195 " "	69.5
13.00 "	197 " "	69.2
23.00 "	206 " "	67.8
28.00 "	200 " "	68.7
30.00 "	215 " "	66.4
31.00 "	200 " "	68.7
32.00 "	206 " "	67.8
33.75 "	641 " "	00.0

Using the figures presented by the actual observations during the operation of the subsiding tanks, the relative range in removal of suspended matters in different periods of subsidence may be estimated, as shown in the following table:

Period of Subsidence	Percentage Removal of Suspended Matter		
	Maximum	Minimum	Average
24 hours.....	85	25	62
48 "	90	30	68
72 "	95	40	72
96 "	95	45	76

Owing to the fact that the data from the operation of the subsiding tanks did not include the period of winter freshets, it is probable that the above percentages are slightly too low for annual averages. Thus the 72 per cent recorded for 72 hours of subsidence seems to be less correct for an annual average than 75 per cent, as previously stated.

THE REMOVAL OF ORGANIC MATTER BY PLAIN SUBSIDENCE.

Those organic particles which are suspended in a water naturally tend to subside, and their removal by this means seems to vary with their character and amount, and with the period of subsidence. Examination of the records of operation of the subsiding tanks shows that the maximum, minimum, and average removals of nitrogen as albuminoid ammonia were 76, 5, and 45 per cent respectively; while the corresponding figures for oxygen consumed were 64, 6, and 42 respectively. As there was no appreciable change in the amount of the dissolved constituents, the amounts removed were wholly in suspension; but the percentage removal is determined as a percentage of the total. Concerning the suspended organic matter, as indicated by the nitrogen as albuminoid ammonia, the percentage of removal was found to be 68 on an average.

THE REMOVAL OF BACTERIA BY PLAIN SUBSIDENCE.

In the operation of the subsiding tanks, with periods of subsidence ranging from one to over four days, it was found that for most classes of water a large percentage of the bacteria present in the river water was removed by subsidence in the first day. At times there was a continual decrease in the numbers of bacteria during the use of the lot, due to subsidence during drawing, but as a rule this did not amount to any very large percentage.

The lowest average removal during these investigations in the probable absence of growths was 19 per cent on lot No. 177, with an average of 34.9 hours of subsidence. At the beginning of the use of this lot (10 hours subsidence) the removal was 12 per cent, and at the end (after 60 hours subsidence) the removal was 28 per cent.

The maximum average removal was 97 per cent, which was obtained on lots Nos. 76, 79, and 80, with 82.1, 67.7, and 82 hours of subsidence respectively. The removal on lot No. 125, which had the longest period of subsidence (136.4 hours), was only 75 per cent.

The average removal on all observations at 72 hours was 75 per cent, but for the entire investigations, with an average of 61.8 hours subsidence, the average removal was 62 per cent.

NORMAL OPERATION OF THE ENGLISH FILTERS.

The general procedure of regular operation of these filters is herewith presented.

Continuous Plan — All of the filters were operated on the continuous plan, and the water stood about 4.2 feet above the original sand surface in each filter, except at times of scraping. The valves at the filter on both the inlet pipe and the outlet pipe were normally kept wide open. As was stated in Chapter II, a practically constant level of the water in the filters was maintained automatically by the aid of the regulating tank.

Regulation of Rate — By means of the valve at the meter, which in each case was placed at the end of the outlet pipe extending to the meter room beneath the main platform, the rate of filtration was regulated as required. The rate was observed three times daily, and it was changed when it was found to be different from the normal rate by more than 5 per cent.

Loss of Head — In about fifteen minutes after the adjustment of the rate of filtration, observations were taken upon the loss of head of the water as it flowed through the respective filters.

Head Utilized — The above features constituted the normal operation of the filters up to the time of scraping. Loss of head observations usually served as the guide to the decision as to when the filters should be scraped. In the case of each filter the first scraping was made when the loss of head reached the maximum available head, about 13 feet. As the horizontal section of greatest frictional resistance in an English filter is at the surface of the sand layer, only about 4 feet of the available head was positive, the remaining 9 feet being negative. It was found that the negative head (suction) reduced the pressure on the water within the sand layer to a point where the nearly saturated water gave off air which accumulated in the interstices of the sand layer. These accumulations of air, as will be brought out fully beyond, increased the frictional resistance of the filters so rapidly that only a comparatively small quantity of water was filtered after the loss of head equalled the positive head or depth of water above the sand.

Beginning in May, after the first scraping of each filter, it became the normal custom to scrape the filters when the loss of head reached 4 feet, practically equal to the positive head. In a number of cases the filters were scraped when the loss of head was much less than 4 feet. During the very turbid water in the river at the time of the August rise, the filters were scraped, when the loss of head reached only 2 feet, in order to aid in lessening the deep penetration of the clay in the subsided water down into the sand layer. The several filters were also scraped at times, independent of the total loss of head, when it was apparent that disturbances had occurred at the surface of the sand layer. The disturbances were due to animal life, as described beyond, and produced to a greater or less degree the inadmissible result of unequal rates of filtration through the sand layer.

Scraping — When it was decided to scrape a filter, the valve on the inlet pipe at the filter was closed, and the water above the sand was removed by filtration at the normal rate. Owing to the steadily decreasing head, it was necessary at such times to adjust the rate at more frequent inter-

vals than ordinarily. The valve on the outlet pipe was closed when the water level in the sand had reached at least 1.0 foot below the surface, though as a rule the filter was drained nearly dry. After the upper portion of the sand layer became fairly dry, usually at two to three hours after the water had disappeared from the surface, some thin boards were placed upon the sand layer, to prevent the boot heels of the workmen from making holes in the sand. The workmen with square-edged molders' shovels then scraped off the surface of sand to the desired depth. Owing to some unevenness in the surface of the sand during the first few months of operation, it was the custom to level the surface somewhat.

Depth of Scraping — Concerning the thickness of the layer of sand which was removed, the procedure was modified in the course of the investigations in accordance with the evidence obtained. This will be described more fully just beyond. In general terms it may be stated that the scrapings up to about August 1 removed practically all of the sand which was distinctly discolored; but after this date the scrapings were not thicker than about one inch, independent of the distance to which the discolored sand extended.

Filling from Below — On completing the scraping of the sand surface, the filters were uniformly filled from below with filtered water at the same rate at which the water passed through the particular filter when in normal operation. Up to June filtered water was taken from an adjoining filter through the "side-filling" pipes. This was not thoroughly satisfactory, owing to difficulties in controlling the rate of flow. After this date the filtered water was applied below through the outlet pipe, which was disconnected just above the meter, and to which was attached a hose receiving filtered water through another meter, either from one of the other filters operated at the same rate, or from the wash-water tank used in connection with filter No. 20. With proper attention the filters could be safely filled in this manner from below, thus driving the air from the pores of the sand layer and avoiding disturbances in the sand which would result in channels of lessened resistance.

The filtered water applied below was allowed to rise until it covered the inlet pipe, about 1.5 inches above the original surface of the sand layer. Then the supply of filtered water was shut off and the valve on the inlet pipe was opened very slightly at first in order to fill the compartment above the sand to its normal depth with subsided water, without disturbing the surface of the sand.

Resumption of Filtration — Normally the outlet was opened and filtration at the prescribed rate was begun as soon as the subsided water above the sand had reached its usual level. At the time of the August rise, when the subsided water contained comparatively large quantities of very fine clay in suspension, the water above the sand was allowed to settle over night before opening the outlet, and the rate of filtration for the first day was reduced to about 60 per cent of the normal. Directly following a scraping of a filter a special series of samples of the effluent was taken uniformly, in order to learn the bacterial efficiency of the filters following this part of the operations.

Resumé and Conclusions Upon the Tests with the English Filters.

Expressed in brief terms, a resumé with conclusions as to the applicability and efficiency of the fifteen original filters of the English type in solving the local problem may be stated as follows:

Inapplicability of English Filters in the Clarification and Purification of the Unsubsided Ohio River Water at Cincinnati.

While it is true that for about four months in the year English filters are applicable for the clarification and purification of the unsubsided Ohio River water with satisfactory efficiency and at a reasonable cost, yet for the balance of the year the large amounts of suspended matter in the river water make these filters inapplicable in unqualified terms.

Inapplicability of English Filters in the Clarification and Purification of the Ohio River Water at Cincinnati after Plain Subsidence for about Three Days.

Experience in the operation of these experimental filters, under the conditions stated, showed that the preliminary treatment of subsidence for three days was insufficient to prepare the river water so that at all time it could be satisfactorily treated by these filters as constructed and operated. The situation with reference to the leading factors of practical significance may be reviewed as follows:

Clarification.

The evidence shows that the effluents would be satisfactory on an average for seven to eight months in the year; but for the remaining portions of the year, made up of the periods of freshets, the effiuent would be markedly turbid and brownish at times, and as a rule it would be far from the clearness which the citizens would have a right to expect from a plant which would necessarily represent a considerable cost.

Bacterial Efficiency.

After the first two or three weeks of operation the filters showed a satisfactory bacterial efficiency so long as the applied water did not become excessively turbid for a fairly long period. Under the latter conditions, such as would arise during the long and heavy winter freshets, there are good reasons for believing that deterioration in the bacterial quality of the effluent would be quite a serious matter.

While it is true that in the light of our present knowledge upon the science and art of water purification, these filters ordinarily gave very satisfactory bacterial efficiencies, still it is not to be forgotten that they are not germ proof. In substantiation of this is the evidence upon the passage through the filters of *B. coli communis,* the leading fecal bacterium, which was present quite regularly in the applied water. Weekly (or bi-weekly) tests were made for the presence of this germ in 50 cubic centimeters of each of the effluents. The results of these tests are summarized in the following table, where it is seen that in nearly half of the cases on an average this species of bacterium was found in the effluent.

SUMMARY OF THE RESULTS OF TESTS FOR THE PRESENCE OF B. COLI COMMUNIS IN THE SEVERAL EFFLUENTS.

Effluent of Filter Number	Number of Tests Made	Percentage of Tests which gave Positive Results
1	6	50
2	4	0
3	1	100
4	10	40
5	6	17
6	1	0
7	9	33
8	6	50
9	5	20
10	2	0
11	3	33
12	1	0
13	24	46
14	10	50
15	1	100

Removal of Organic Matter.

Independent of the organic matter associated with the turbidity of the effluents, the efficiency of the filters in this respect was satisfactory. Furthermore, it is very doubtful whether the organic matter suspended in the turbid effluents had any sanitary significance whatever, practically speaking.

Construction of Filters.

Underdrains — The underdrains should support the sand layers completely, and should be arranged to allow equal rates of filtration through the entire area of the filter. In practice, the factor of safety with reference to supporting the sand layer should be greater than in these filters.

Kind and Size of Sand — The most suitable available sand for local filters of this type is that which is pumped from the sand bars in the river opposite Coney Island. Its effective size averages 0.22 millimeter, and its uniformity coefficient is 1.5 There is no need of washing it before its placement in the filters.

Thickness of Sand Layer — At times of freshets thick sand layers, by virtue of their greater capacity to store clay particles, are more efficient than thin layers. But 5-foot layers during long freshets were found to be inadequate. From a theoretical standpoint it seems probable that, with conventional rates of filtration, sand layers could be made sufficiently thick so as to yield a satisfactory effluent at all times. The available evidence, however, indicates that the cost of such a procedure would make it impracticable.

Under normal conditions — that is, at times when the effluent would be satisfactory in character — it was found that 3-foot layers were substantially as efficient as 5-foot layers.

Depth of Water — The depth of water above the original sand surface, 4 feet, could not apparently be modified to advantage.

Reserve Area of Filters — To maintain the normal yield of effluent during the winter freshets, it would apparently be necessary to double approximately the conventional (20 per cent) reserve limit of filter area.

Covers of Filters — At the outset it does not seem advisable to cover the filters; but as the increased water consumption reduced the reserve area of filters, it is believed that it would be found better to cover the filters rather than increase the area, under the existing local conditions.

Applied Water Screens — Screens should be arranged to remove from the applied water, so far as practicable, all fishes, earthworms, and other forms of animal life.

Regulating Devices — The devices for regulating the flow of the influent and effluent water should be made as efficient and automatic as possible.

Sand-Washing Plant — Economy demands that a sand-washing machine with necessary appliances for moving the sand should be an adjunct of the filter plant. The ejector type of washer was used with satisfactory results.

Operation of the Filters.

Rate of Filtration — Under favorable conditions with regard to the composition of the applied water, where it was possible to obtain a satisfactory effluent from these experimental filters, there was no marked difference in efficiency in the three rates tested — 1.5, 2.6, and 4.0 million gallons per acre daily. From this evidence it is clear that under normal conditions a rate of 4.0 million gallons per acre daily would be most advisable.

When the applied water contained large amounts of clay the low rate was most efficient, because the storage capacity of the sand layer was exhausted much less quickly than at higher rates. But a rate of 1.5 million gallons per acre daily would not carry satisfactorily a filter, with a sand layer five feet in thickness, through the long freshets.

Unquestionably it is possible to reduce the rate of filtration so that the subsided water could be satisfactorily clarified and purified at all times, but the cost would be clearly prohibitive.

Uniformity of Rate — The rate of filtration should be practically uniform, and provisions should be made for regulating the operation of the filters to that end.

Maximum Loss of Head — Experience showed that the loss of head ought not to be carried beyond the depth of the water above the sand layer. When the character of the effluent is satisfactory with regard to appearance, there is no reason why advantage can not be taken of the full positive head.

Procedure at Times of Scraping — No serious diminution in the quality of the effluent followed the fixed procedure finally adopted, as follows: Drain the filter so that workmen can stand on the fairly dry sand layer; scrape off one inch or less; fill from below with filtered water at the regular rate until the water stands several inches deep upon the sand; turn on the applied water slowly at first so as not to disturb the sand surface; and when the basin is full begin filtration at once at the normal rate.

No appreciable advantages were noted from allowing the applied water above the sand to settle, nor from reducing the rate of filtration for a short period when resuming filtration. With ordinary care there was no need of wasting any of the effluent just after scraping.

Frequency of Scraping — With this river water after about three days subsidence, and with a rate of filtration of four million gallons per acre daily through a filter of fine sand, it is estimated that on an average there would be required, according to the above stated procedure, about twenty scrapings per year.

Quantity of Sand Removed — Under the conditions stated above, it is estimated that the quantity of sand removed by scraping would average about 2.25 cubic yards per million gallons of effluent.

Reconstruction of Sand Layer — In the case of filters originally having sand layers three feet in thickness, it is probable that they would have to be restored to their original thickness about once a year, certainly oftener than every two years. If special care were taken to guard against clogging at the junction of the old and new sand, it is believed that several years might elapse without having to take out all of the sand down to the gravel layers, and wash it before replacement.

Sand Washing — The evidence shows that it could be cheaper and better to wash the sand removed by clogging rather than use new sand for maintaining the thickness of the sand layers. By the ejector type of sand washer it was found that the fine Coney Island sand, removed in a clogged condition by scraping, could be washed satisfactorily with twenty-five volumes of (fairly clear, but unfiltered) water to one volume of sand.

Final Conclusions — In the absence of heavy and long-continued freshets in the river, three days subsidence would be adequate to allow the local water to be satisfactorily clarified and purified by this type of filter and at a reasonable cost. When heavy and long-continued rises in the river do occur, the method under consideration would not be a success, with filters constructed within conventional limits as to thickness of sand layer and operated within conventional limits as to rate of filtration. Their failure under such conditions would be due to the excessive turbidity of the effluent; the diminution in bacterial efficiency toward the end of long rises; and to the abnormal expense of cleaning the sand layers.

It would be possible by increasing sufficiently the thickness of the sand layer, or by decreasing sufficiently the rate of filtration, or by a combination of these two modifications, to obtain uniformly an effluent of satisfactory character and appearance from the local river water after plain subsidence for three days. But the cost of such procedures would clearly make them prohibitive.

To make use successfully at all times of English filters it would be necessary at times of freshets to give to the Ohio River at Cincinnati further preparatory treatment than is afforded by three days of plain subsidence.

MODIFIED ENGLISH FILTER SYSTEM.

On July 6, 1898, it was recommended, after reviewing the results obtained from the operation of the original English filter from March 28 to June 30, inclusive, that modifications be made in the experimental plant. The object of these modifications was to test the practicability of provisions to secure at times of freshets in the river supplementary clarification of the river water following plain subsidence for about three days, and preceding filtration through filters of the English type.

For convenience this proposed method is called the *modified English system of purification.* Attention is especially called to the expression "system of purification," comprising plain subsidence, coagulation, and supplementary subsidence (when needed) and filtration. It is much more comprehensive than the conventional term filtration, and is much more correct under the conditions to be considered here.

Authority was granted by the Board of Trustees on July 27 to proceed with the modifications recommended. In addition to stopping permanently a number (seven) of the original experimental filters, coagulating, and supplementary subsiding basin E and filters Nos. 16 and 17 were constructed.

Before describing the results of the operation of these three new devices, the situation at the commencement of this portion of the investigations will be explained more fully.

Principles Upon Which Were Based the Proposed Modified System of Purification.

The available evidence on July 1, based on the results of operation for three months of the original filters, showed that plain subsidence for about three days was insufficient to prepare the river water of average composition for successful and practicable clarification by the English type of filters; and during about half of this period these filters were a failure, practically speaking. Furthermore, the indications were that during the latter part of prolonged freshets in the river the results from the filters (constructed and operated within conventional and practicable limits) would be unsatisfactory in almost every respect.

Under these conditions the proposition of making satisfactory use of English filters in a system of purification for the local river water became, practically, one of further preparation by additional clarification of the turbid river water during freshets before its application to the filters. Of course, this additional clarification could be obtained by plain subsidence for a longer period; but this procedure would be very expensive, because the fixed capital charges for interest and sinking fund would be constant, whereas the need of additional preparation beyond plain subsidence for about three days would be required in the course of a year, only about one-third of the time in the aggregate. Economy demanded, therefore, that, if possible, means be secured whereby the necessary supplementary and intermediate treatment could be obtained at a reasonable cost when actually used, and with only a very slight expense when at times of clear water in the river it would not be needed.

So far as our knowledge upon such matters went, this could best be done by applying a coagulating chemical in suitable quantities to the regularly subsided water, when excessive amounts of clay make it very turbid, and then allowing the coagulated clay to subside in a comparatively small basin before the water reached the filters. By a suitable amount of the coagulant is meant such a quantity as would cause the effluent of the coagulating basin to contain no more than an average amount of about 40 to 50 parts per million of suspended clay. It will be recalled that this was the normal limit of clay in the applied water, which can be regularly and satisfactorily handled by English filters under normal conditions.

It will be seen at once that an important function of the coagulation basin was to remove almost completely the gelatinous precipitate formed by the applied chemical (coagulant), otherwise it would pass on to the filter and clog the surface of the sand layer so rapidly that the procedure would be impracticable.

Relative to the particular coagulating chemical to be used, this is not a specification in the method. As a matter of fact, that chemical should be used which would accomplish the work at the least cost, and produce no objectionable change in the character of the water, practically speaking. At the present time apparently those conditions are best fulfilled by sulphate of alumina, and therefore this chemical was used during these tests. It is quite possible, however, as our knowledge of coagulating chemicals advances, that it might be found advantageous to substitute some other chemical for the one stated. If this were done, it would apparently not involve any essential changes in the plant for this modified method.

The English filters themselves, both with regard to construction and operation, but independent of efficiency and economy, would not be affected by this modification in the system. In the two new experimental filters advantage was taken of the best and most practicable conditions, as represented by our experience with the fifteen original filters of this type.

Objects of the Experimental Investigations with Regard to the Modified English System.

In brief terms, the principal objects of the tests described and discussed in this chapter may be outlined as follows:

1 — To determine, so far as practicable, the most economical period to provide for the coagulation and supplementary subsidence of the plain subsided water after the application of the chemical to it and before its passage on to the filters.

2 — To determine approximately the amount of chemical which would be required during freshets in the river to accomplish the coagulation needed for the supplementary clarification.

3 — To learn the influence upon the efficiency and cost of operation of English filters of applied water containing at all times suspended clay only within the limits which the filters can handle and also containing possibly at certain times a small amount of the gelatinous precipitate which failed to subside in the secondary subsiding basin.

Conclusions Upon the Tests of the Modified English Filters.

Taking all the factors into consideration, the available evidence indicates that under the local conditions it would be somewhat more economical and convenient, and therefore more advantageous, to apply the chemical in the modified system before the entrance of the river water into the subsiding reservoirs. It is true that this would make the managament of a plant more difficult of the two procedures considered; but with any procedure skilled and competent men would have to be placed in charge in order to insure satisfactory results. And the effluent would be slightly less desirable, but still satisfactory, for boiler purposes.

In connection with this decision it is to be clearly borne in mind that it is necessary to give considerable weight to the influence of local conditions where the topography of available purification sites makes the construction of an adequate plant expensive and difficult to accomplish without separation into several isolated portions. Under different topographical conditions, and with the same river water, it is probable that this decision would be reversed to advantage, as its economy in many instances would be very small and incommensurate with the increased difficulties of operation and the undesirability of using the larger quantities of chemical necessitated by the application to the unsubsided river water.

THE EFFICIENCY AND ECONOMY OF THE FILTERS IN THE MODIFIED ENGLISH SYSTEM.

Quality of the Effluent — With filters of good construction and intelligent operation of the entire system, experience shows that the quality of the effluent, judged by the best standards of the present time, would be perfectly satisfactory with respect to the removal of bacteria, organic matter, and the minute clay particles.

Relative to the satisfactory bacterial efficiency obained from filters Nos. 16 and 17, this is shown by the following average results from August 15, one week after the filters were put in operation, through September 24, when filter No. 17 was permanently stopped.

River water	10,200	Bacteria per Cubic Centimeter.	
Subsided water	2,100	"	"
Effluent of filter No. 16	41	"	"
Effluent of filter No. 17	32	"	"
Bacterial efficiency of filters alone		No. 16	98.0
		No. 17	98.5
Bacterial efficiency of subsidence and filters		No. 16	99.6
		No. 17	99.7

In the case of filter No. 16 the total average bacterial results from August 15 to December 13 when it was permanently stopped, are as follows:

River water	18,300	Bacteria per Cubic Centimeter.	
Subsided water	5,000	"	"
Effluent of filter No. 16	55	"	"

The above data correspond to bacterial efficiencies of 98.9 and 99.7 when computed from the subsided water and river water, respectively.

The modifications stated would not necessarily remove entirely the possibility of deterioration in the quality of the effluent, due to disturbance of the surface of the sand layer by animal life. It is believed that this difficulty would be practically manageable as a rule by the judicious use of sufficiently fine screens.

During freshets there would be a marked increase at times in the sulphate of lime and carbonic acid in the effluent. But from the evidence available, there is no reason to believe that these changes would be seriously detrimental, although undesirable, as the effluent apparently at such times would be practically as good for boiler purposes as the the river water at times of very low water in the river.

Elements of Cost of Construction and Operation — Experience showed that 36 inches in thickness of the fine Coney Island sand, in an unwashed condition, would give satisfactory results. A depth of four feet of water above the original sand surface was satisfactory, and the loss of head could be carried to this point (4 feet) provided no surface disturbances occurred. Negative heads are impracticable.

With a satisfactory and adequate treatment of the river water when muddy, complications from deep penetration of clay into the sand layer would not arise with rates from 3 to 4 million gallons per acre daily. The same was found to be true with a rate of 5 million gallons, but the indications were that the suspended clay during the latter part of prolonged rises in the river should perhaps be kept as low as 40 parts per million, rather than 50 parts per million, as could be safely handled with somewhat lower rates and thicker sand layers.

To some it might seem more advisable to reduce the number of days and perhaps, to a slight degree, the actual rate of application of chemical by taking more advantage of the storage capacity of the filters through thicker sand layers and lower rates of filtration. At some places it is quite likely that local conditions would make such a procedure advisable. But at Cincinnati the available evidence clearly indicates that such steps would not be wise for the following principal reasons:

1 — Owing to the fact that it is impracticable, by increasing the thickness of the sand layer or decreasing the rate of filtration, to obviate the use of a chemical at times of heavy freshets, it is not possible in this modified system, even if the capacity of the filters to store clay were materially increased, to do away with the cost of skilled supervision or the undesirability of comparatively large amounts of chemical during very turbid water in the river.

2 — While it is cheaper and more logical, upon general principles, to make a preliminary treatment supplementary to subsidence for about one-third of the year sufficient to allow filtration proper to be conducted as satisfactorily and as economically as would be the case for two-thirds of the year in the absence of such treatment; it is especially so at Cincinnati, where the topography of the ground makes filter construction unusually expensive, and where in a hilly country it is very difficult to find suitable locations in one place or even closely adjoining places for a plant of 80 million gallons capacity.

The indications are that a net rate of three million gallons per acre daily could be safely depended upon from open English filters of this system. Were it not for the complications during cold weather in scraping, it is believed that materially higher net rates could be obtained. Whether it would be wiser to cover the filters or extend the size of the plant to meet future requirements is an open question, and should be settled by practical experience.

The thickness of the sand layer removed at a single scraping ranged from 0.75 to 1.0 inch. The volume of sand removed per million gallons of effluent is estimated at about 1.75 cubic yards.

According to the available data, it is estimated that, with actual rates of from about 4 to 5 million gallons per acre daily, the number of scrapings per annum would be from about 15 to 20, respectively.

The regular procedures at times of scraping, with no settling of the water above the sand and with no reduction in the rate of filtration upon the resumption of filtration, was satisfactory.

During these portions of the year, aggregating about 4.5 months, when the river water contained less than from 100 to 125 parts per million of suspended matter, it would be advantageous and economical as a rule to apply the river water directly to the filters, without preliminary subsidence. By this means the capacity of the filters to retain clay at and near the surface of the sand layer would be increased, due to the organic matter present in the river water when fairly clear.

Necessary Supervision and Attention Required for the Operation of This System.

It would be a much more difficult undertaking to operate a modified English system of purification than an English system applicable for the work for which it was constructed. The reason of this lies in the judgment which would be required to know when and how much chemical should be applied to the water. Safety and economy demand that this system should be in charge of men of adequate training and experience in this line of work, with sufficient attendants and a laboratory force to provide the necessary analytical data as promptly as possible.

Without such supervision and attention, the citizens would have no surety against gross mismanagement and failure of the plant at times of heavy freshets in the river.

Final Conclusions.

The evidence shows that the modified English system of purification is applicable to the Ohio River water at Cincinnati, based on the satisfactory clarification and purification of the water. It would, however, be very much more difficult to operate, and somewhat more expensive, than is understood to be the case with those purification works of the English method now in use at various cities.

AMERICAN SYSTEM.

On August 17, 1898, the available evidence indicated clearly that a satisfactory solution of the local problem would involve a decision between the modified English method and the American method of purification. The former would involve the application of chemical only at times of very turbid water, and the filtration of the water after an interval of subsidence at a comparatively slow rate through filters of the English type. In the case of the American method, coagulant at all times would be applied; and the water, after such treatment and at interval for coagulation and sedimentation, would be passed through filters of the American type at a very high rate as compared with that of the English filters.

In the decision between these two methods or systems of purification the deciding factor would be apparently one of cost, there being no apparent reasons why either method could not be made under proper supervision to give equally satisfactory results, so far as the quality of the effluent was concerned.

As the evidence then stood, this decision would have to be based on previous experiences elsewhere so far as the American method was concerned, or on bottle experiments made in the laboratory here. Neither of these solutions seemed adequate for a decision in regard to a system of the magnitude necessitated here, the former on account of the difference in the character of the water, and the latter because of the lack of data by which to interpret satisfactorily in a practical way the results of coagulation in small bottles.

This situation was outlined to you in a special report dated August 17, 1898, in which it was recommended that a four-foot filter of the American type be installed, and that suitable chemical devices and coagulating basins should be arranged in connection therewith. In order to provide a sufficient quantity of subsided water for the operation of this new filter, it was necessary to stop permanently a number of the original filters, as previously stated.

These recommendations having been approved by you and by the Board of Trustees on August 19, 1898, work to this end was at once commenced. The system, including suitable devices for the application of chemical, three basins for the coagulation and partial clarification of the water by sedimentation, and a four-foot filter of the American type, constructed by and purchased from the O. H. Jewell Filter Company, of Chicago, Ill., was completed by September 14, 1908, and was put in operation on the afternoon of that day.

The General Method of Operation of the American System.

Practically speaking, the American system is composed of three main divisions, each independent of the others, but satisfactory operations of all being essential for the successful operation of the system. These portions may be classified as follows:

1 — The devices for the preparation and application of the chemical.

2 — The basins in which coagulation and partial clarification of the water by subsidence takes place.

3 — The filter through which the coagulated and partially clarified water is passed as a last step in the process.

Viewing the system as a whole, the water to be purified is first treated with the desired amount of chemical (applied in the form of a dilute solution) and it is then passed through the coagulating basins. In these basins the decomposed coagulant aggregates the clay particles and other matters, and when any of the aggregated particles reach a sufficiently great subsiding value they settle out. After passing through the basins, the water, in which all of the suspended matters present are more or less com-

pletely aggregated into relatively large particles, is passed on to a bed of sand. The latter acts as a strainer and removes the remaining coagulated particles, leaving the effluent clear and practically free of such matters, including bacteria.

APPEARANCE OF THE EFFLUENT AND THE REMOVAL OF ORGANIC MATTER IN THE AMERICAN SYSTEM.

Without exception it was found that, under the conditions of operation at this plant, the effluent was brilliant in appearance, and the removal of organic matter was satisfactory, at all times when the bacterial efficiency was satisfactory. As the bacterial efficiency is the point of greatest importance, it may be stated positively that when the American system was operated here so as to give satisfactory bacterial results, no attention was required for the questions of appearance of effluent and removal of organic matter, because in the latter respects the results were practically perfect. So far as could be learned, nitrification was not an appreciable factor in the removal of organic matter.

Comparing the behavior of English and American filters in this respect, it is seen that there is a complete reversal in the relation of the results obtained. That is to say, while English filters gave good bacterial results and a poor appearance of the effluent and indifferent or poor removal of organic matter, the American system could give just the opposite.

The explanation of this sharply defined reversal in the relation of the results obtained from English and American filters, under the existing local conditions, is not perfectly clear. It appears, however, to be associated largely with differences in the action of the coagulating chemical upon the bacteria, the minute particles of clay and of organic matter in the applied water, and with their relative sizes before coagulation.

In the case of English filters, it appears to be the difference in sizes which causes largely the practically complete removal of bacteria, with very imperfect removal at times of the much smaller particles of clay and suspended organic matter. When a coagulating chemical is added to such a water before its application to an American filter, it seems that the chemical has a greater power to coagulate and to aggregate the clay and organic matter into relatively larger masses than is the case with the bacteria. Furthermore, the adhesiveness of the gelatinous aluminum hydrate to the rough surface of the clay particles appears to be distinctly more than to the comparatively smooth membranous walls of the bacteria. Combining these two factors, they appear to go a long way towards explaining the stated differences in the behavior of the two types of filters, as judged from present information.

The actual bacterial efficiency accomplished by the American filter (No. 20) alone and in connection with plain subsidence is shown in the summaries below. The first one includes all bacterial results after the first week of operation and the second covers the same period but excludes the results from December 6 to 10 and 22 to 24, both inclusive when changes were made in the sand layer, and the new sand was put in place in a more or less frozen condition.

SUMMARIES OF BACTERIAL RESULTS — AMERICAN SYSTEM.

PERIOD	BACTERIA PER CUBIC CENTIMETER			BACTERIAL EFFICIENCIES	
	River Water	Subsided Water	Effluent of Filter No. 20	Filtration alone	Filtration and Subsidence
Sept. 21, 1898 to Jan. 25, 1899	27,200	12,600	400	96.8	98.5
Ditto, but excluding Dec. 6 to 10 and Dec. 22 to 24, 1898	25,000	10,900	160	98.5	99.4

It is hardly necessary to state that the bacterial efficiency of filtration proper is computed by dividing the difference in the numbers of bacteria in the subsided water and in the effluent by the former number; and of filtration and subsidence in a corresponding manner from the numbers of bacteria in the river water and in the effluent.

Relative to the removal of bacteria, it is believed that the quantity of applied chemical employed in the operation of filter No. 20 was rather too low when viewed strictly from a hygienic standpoint, especially during the earlier part of the operations. As nearly as can be estimated, this filter was operated on a basis of an annual average application of about 1.25 grains of chemical per gallon of applied water. This quantity would enable the system to yield a brilliant effluent and give a good removal of bacteria — about 99 to 99.5 per cent for an annual average removal of the river water bacteria.

But if about one-third of a grain of chemical per gallon in addition were applied on an average, the evidence indicates that the bacterial results would be as good as is practicable to obtain by any method now known. That is to say, the bacteria in the effluent would average less than 100 per cubic centimeter, and the annual average removal of the river water bacteria from present evidence would amount to fully 99.5 per cent.

The leading points in this connection, based upon the results of these investigations, are briefly, as follows:

Preliminary Treatment of the River Water.

Plain subsidence of the river water for three days is fully as long preliminary treatment as it is practicable to give to this water. In fact, with an adequate coagulating and supplementary basin, it is very doubtful whether it is advisable to provide a period of more than one day, except for reasons independent of the purification of the water.

At times, however, it is clear that it would be advantageous not to use the plain subsiding reservoirs, but deliver the fairly clear river water directly to the coagulating basin, and thus reduce the cost of pumping.

Application of Chemical.

Kind — At present, sulphate of alumina is apparently the most suitable chemical to apply for the coagulation of this water. If a more advantageous chemical were found it could probably be employed without the necessity of changes of serious importance.

Method of Application — Under the local conditions a gravity discharge of a weak chemical solution under a constant head would be most advisable, as was used in these tests.

Places of Application — The evidence indicates that at least two different places of application should be provided; and it is likely that at times athird and intermediate place could be used to advantage, but with questionable economy. These three places would represent about 0.5, 2.5, and 6.0 hours, respectively, as the average period of flow from the point of application to the entrance of the water into the filters. At no time, however, would the chemical be applied at more than two places at once; and the middle one of the periods stated could be omitted to best advantage if only two should be provided.

Regulation of Flow — Owing to the corrosive action of solutions of sulphate of alumina, the required tanks, pipes, and fittings should be of material not subject to this corrosive action. To regulate the flow, meters with complete hard rubber linings should be used.

Provisions for Coagulation and Supplementary Subsidence.

The evidence appears to be very decisive that a period equivalent to at least six hours flow should be provided, with places for the application of chemical, as mentioned above.

Amount of Head Required.

The evidence at present shows that about 12 feet represents the economical limit to which the total loss of head can be carried under all circumstances. However, 10 feet would be practicable and a reasonably satisfactory head, but would make the percentage of wash water rather higher than necessary in the event that fine sand and higher rates than those stated below were used.

Rate of Filtration.

Normally a rate of 125 million gallons per acre daily could be satisfactorily employed, and the evidence shows clearly that rates distinctly higher than this could be safely used on special occasions and also to meet the increased consumption of water.

To locate the maximum limit definitely at this time appears to be unwise, in the absence of the more decisive evidence which would be secured in practice.

Regulation of Rate of Filtration.

This can best be done by having a free gravity flow of the water on to the filters, and having the rate of flow regulated by automatic controllers placed at the outlet pipes. The question of the most suitable form of controller for filters of the size stated is one which requires further study and development.

Washing the Sand Layer.

The method of washing with filtered water, with accompanying agitation, until the sand layer is comparatively clean, is as satisfactory as seems practicable to obtain in the light of present evidence.

Height of Filters.

By eliminating the coagulating basins from immediate connections with and as a part of the individual filters, a height of five feet is ample when a negative head is employed, except as required to provide for different levels of the applied water.

Character of the Sand Layer.

The use of 20 inches of fine sand from the bar in the river opposite Coney Island was found, on the whole, to be superior to the coarse sand formerly in use. It is an open question, however, whether it is not possible to secure very nearly as good results with 30 inches of sand of an intermediate size, and thus reduce the percentage of wash water.

Under these circumstances it would be advisable, in our judgment, to provide for a thickness of 30 inches in all cases, and in half of the filters use 20 inches of fine sand and in the other 30 inches of medium sand. As the river sand is comparatively inexpensive, a change could be ultimately made to the sand layer which extended experience proved to be better.

Filtered Water Exits.

The available evidence indicates that it is not practicable to use perforated discs or plates capable of supporting fine sand. This being true, the use of slotted strainers is apparently necessary. The ones in use would clearly become clogged in time, so that it would be necessary to remove them for cleaning from time to time or to replace them.

As has been pointed out already, the strainers should be arranged, if possible, to allow all of the sand to be washed and reached by the teeth of the agitator.

Agitation of the Surface of the Sand Layer.

Although surface agitation could not be used with satisfaction when treating the subsided water, it seems possible to use it to advantage when the river water is sufficiently clear to allow the omission of plain subsidence. Accordingly, this should be borne in mind in the construction of the filter tanks and the agitators.

Disposal of Wash Water.

There seems to be an opportunity for economy with no corresponding disadvantages, by pumping (at least at times) the wash water after it leaves the filter into the force main leading to the plain subsiding reservoirs.

Accessibility of Parts.

To facilitate examination and repairs, the principal parts, notably the strainer system, should be made as accessible as is practicable.

Conclusions.

The evidence shows that the American system of purification is applicable to the Ohio River water at Cincinnati, based on the efficiency and cost of its operation.

FINAL RESUMÉ AND CONCLUSIONS.

Eliminating from consideration in this chapter, for the most part, those points of a purely technical nature which have been discussed at length earlier in this report, the facts of practical significance learned during these investigations may be summed up as follows:

Inapplicability of English Filters to the Clarification and Purification of the Unsubsided Ohio River Water at Cincinnati.

In the purification of those classes of water for which the English type of filters is strictly applicable, the available evidence indicates clearly that this method is a satisfactory one when the filters are properly constructed and operated. Further, so far as our knowledge goes, this method is ordinarily somewhat more efficient and more economical for water for which it is readily applicable than any other process of purification which has received serious attention.

But in the consideration of this method of purification with reference to the river waters of the Central West, where frequent freshets cause the water to be laden with comparatively large amounts of silt and clay, it is found that English filters have decided limitations in their applicability.

At the outset of these investigations the position was taken, endorsing the recommendation of the Engineer Commission, that the Ohio River water at Cincinnati should receive a preliminary treatment by plain subsidence to prepare the water for clarification and purification by English filters. Experience in the operation of the fifteen original experimental filters of the English type showed the wisdom of this step, because the suspended matter in the river water would increase materially the cost of treatment, and, of still greater importance, would preclude at times the possibility of securing filtered water of satisfactory appearance and character.

For the sake of explicitness it is desired to show, with the data of the fairly normal year of 1898, the proportion of the time when the English filters would be inapplicable in the purification of the unsubsided Ohio River water at Cincinnati. This necessitates fixing an average limit of permissible suspended matter in this river water, and is a difficult matter from present evidence.

In part this is due to variations in the character and in the relative amounts of the suspended silt, clay, and organic matter; and in part it is due to different amounts of clay stored in the sand layer, which affects materially the capacity of the filter to retain the clay of the applied water. During

these investigations the unsubsided river water was not regularly applied to filters; and, with the exception of the results of tests for a few days only, it is necessary to depend upon general information obtained with reference to this point. So far as our information goes, it appears that an average of 125 parts per million is a conservative estimate of the amount of suspended matters in the unsubsided river water, which could be regularly and fairly satisfactorily handled by English filters. But at times this estimated average would be too low, and at other times too high.

On the above stated basis of differentiation between waters for which English filters are applicable or inapplicable, it is found that during the year 1898 these filters could have been used satisfactorily without preliminary subsidence of the local river water on only 132 days, or 36 per cent of the total time. In the light of this evidence it goes without saying that English filters would be a failure in the treatment of the unsubsided water of the Ohio River at Cincinnati.

It is instructive to note in this connection that, owing to the variations in the composition of the river water, English filters without subsidence would be applicable to the local river water only for short periods of time. In fact, they could not have been used with success for ten days at a time in 1898, except during the months of June, July, September, and October.

Inapplicability of English Filters in the Clarification and Purification of the Ohio River Water at Cincinnati After Plain Subsidence for Three Days.

Plain subsidence for three days, as was found by the results of this investigation causes on an average a removal of practically 75 per cent of the suspended matters present in the local river water. Accordingly, a system of purification comprising plain subsidence for three days and English filtration is applicable for water containing more suspended matter than is the case with English filters without subsidence.

The efficiency of plain subsidence in the preparation of very turbid waters for satisfactory filtration through filters of the English type, however, is not so great as would appear at first sight. The reason of this is that the clay particles remaining in the turbid subsided water are more difficult to handle than an equal weight of the mixed silt and clay of the original river water.

While English filters are able to remove satisfactorily on an average about 125 parts of silt and clay of the unsubsided water, actual experience shows that they can regularly handle suspended clay in subsided water in amounts ranging only as high as from 30 to 70 parts (depending largely upon the amount of the clay stored in the sand layer), and averaging about 50 parts per million. But it is true that for two or three days on short rises in the river, or at the beginning of long freshets, the retentive capacity of the sand layer allows of satisfactory results with the clay in the applied water considerably in excess of 70 parts. If this capacity is greatly overtaxed, however, the advantage is merely temporary, as the stored clay is washed out later, producing markedly turbid effluents.

Taking an average amount of 50 parts of suspended clay in the subsided water as the basis of differentiating those days in 1898 when English filters could have satisfactorily clarified and purified the local water after plain subsidence for three days, it is found that these days amount to 197, or 54 per cent of the total time. But, practically speaking, English filters would have been satisfactory in the treatment of the subsided water on more than 197 days in 1898, because the capacity of the sand layer to hold back the applied clay would cause the elimination from the days of failure of those occasions when there were freshets of short duration in the river; that is to say, the capacity of the filters to store clay within the sand layer would allow for a short time applications of clay much in excess of the amounts which could be regularly handled. Based on actual results of operation of the experimental filters, it is estimated that during the year 1898 English filters could have been used with satisfaction in the clarification and purification of the subsided water on 231 days, or 64 per cent of the total time.

While in some instances it is true that the decision as to whether or not the effluent was satisfactory might not coincide with the views of every one, yet, as a rule, the conditions were such as to preclude differences of opinion. In unqualified terms it can be stated that plain subsidence for three days is insufficient to prepare uniformly the Ohio River water at Cincinnati for successful clarification and purification by means of filters of the English type.

Specific Difficulties and Complications in the Treatment of the Local River Water by Plain Subsidence and English Filtration.

It is necessary in this review to call attention to several abnormal characteristics of importance which appeared in the study of the local water, as follows:

1 — The comparative absence of organic matter in the water capable of forming gelatinous films around the sand grains at times when it was needed most. This was apparently due in part to the removal of the organic matter by attachment to sand and silt deposited in the river, and in part to further removal in the subsiding tank.

2 — The minuteness of the clay particles in the subsided water, and difficulties in retaining them at and near the surface of the sand layer, especially in the comparative absence of organic matter adapted to increasing the retentive capacity of the sand.

3 — The disturbances of the surface of the sand layers, and consequent irregularities in the rate of filtration, due to fishes, earth-worms, and other forms of animal life.

Of these three objectionable features, which, so far as our knowledge goes, are not met to any corresponding degree in water actually treated with success by this system of purification, the first two are inherent ones, incapable of ready correction by artificial means, while the third one can be controlled more or less by a proper use of screens. It is by no means certain, however, that screens would remove sufficiently the spawn of fishes or the eggs of angleworms.

Features Wherein Plain Subsidence for Three Days and English Filtration Fail Essentially in the Clarification and Purification of the Local River Water.

The system of purification under consideration was unsatisfactory along three lines, as follows:

1 — At times of prolonged freshets the turbidity of the filtered water was so great that it had the brownish appearance of the unfiltered water, frequently containing over 30 parts per million of suspended clay, an amount and of a character which makes it doubtful whether it could be removed by a second filtration.

2 — At times of freshets the penetration and retention of the clay within the main body of the sand layer would make the cost of scraping greater, and would apparently necessitate the reconstruction of the entire sand layer at much more frequent intervals than is normally the case in present practice with this type of filter.

3 — When the filtered water was turbid and brownish for some little time, there was a marked tendency towards a diminution in the bacterial efficiency of the filters. During the long freshets frequently occurring during the winter the evidence points to the matter as one of serious significance.

The second of these points might be tolerated, if no way could be found to obviate it; but the first and third of these points may be safely stated as prohibitive, in the absence of any practical means of assisting the filters at such times.

Impracticability of Further Preparation of the Local River Water for Treatment with English Filters by Plain Subsidence Beyond About Three Days.

As these investigations showed that English filters are a failure locally, owing chiefly to insufficient preparation of the river water at times of freshets, the next logical step is to consider the best

means of securing more efficient preliminary treatment of the river water. To obtain this by extending the average period of plain subsidence beyond about three days would not be practicable, on the ground of cost, for the following reasons:

1 — Experience shows that the fine clay particles remaining in water which has been subsided for three days subside very slowly, and the increase in the percentage of suspended matters removed is seldom more than 5 for any day beyond the third, and decreases steadily as the period of subsidence is extended. This is shown clearly by the data presented, and is confirmed by the casual observations and analyses made in connection with the efficiency in clarifying the same river water, of the subsiding reservoirs of Covington, where the period of subsidence is about thirty days. On February 20, 1898, a sample of water collected from the outlet of the lower Covington Reservoir was found to contain 52 parts of suspended clay.

2 — The cost of adequate preliminary treatment of the water by this procedure would be disproportionately high, because this amount of preparatory treatment would be required less than half of the time, while the fixed charges for the interest and sinking fund on the cost of constructing the required subsiding reservoirs would be constant.

Under these circumstances economy demands the consideration of other preparatory methods, to be used either with or without the assistance of plain subsidence.

Imperativeness of the Use of Coagulants.

The present evidence is conclusive that the large quantities of very minute clay particles, present in the local river water for periods ranging probably from three to six months in different years (and averaging about four months), can not be removed in a practicable manner in their original condition by subsidence and by filtration through English filters. So far as present knowledge upon this subject goes, there is only one way in which these clay particles can be removed, and that is to apply a chemical which shall aggregate them into flakes or masses, so that it is practicable to remove them subsequently by subsidence and filtration.

In the light of these facts it can be stated in unqualified terms that, for the practical clarification and purification of the local river water, it is imperative at certain seasons of the year to make use of a chemical having the power to aggregate the clay particles.

Two Methods by Which Use May Be Made of Coagulants.

There are two methods by which use may be made of coagulation in the clarification and purification of the local river water. In brief, the two methods, called the modified English system and the American system, may be outlined as follows:

The Modified English System.

In this system or method a coagulant is used only at those times when economical provisions for plain subsidence are incapable of preparing the turbid water adequately for filtration, and in such amounts that the water going upon the English filters may be properly and readily filtered. It is essential in this method that provisions be made to allow the coagulated suspended matters in the water to subside, so that they will not rapidly close up the pores of the sand layer at the surface. That is to say, the water applied to the English filters must be substantially free of coagulated masses of clay.

There were investigated two procedures for the application of the chemical when required, as follows:

1 — Applying the chemical to the plain, subsided water when its condition demanded it, and then allowing the coagulated portions in suspension to subside in a relatively small basin interposed between the plain subsiding reservoirs and the filters.

2 — Applying the chemical to the river water, when required, before the water entered the plain subsiding reservoirs, and allowing the supplementary clarification to take place in the main subsiding reservoirs, thus dispensing with the small intermediate basin.

Each of these procedures has its advantages, but experience indicated that for economical reasons the second one would be preferable.

After getting the applied water uniformly prepared for filtration, the English type of filters can complete the clarification and purification in a satisfactory manner, and with a smaller area of filters than is conventionally considered to be necessary.

The American System.

With this system the chemical is uniformly applied to the water after it leaves the plain subsiding reservoirs, the amount of chemical varying with the amount of suspended matter in the water. To facilitate the operation of the plant and to lessen the total cost of the filtered water, the water should be given an intermediate subsidence after the application of the chemical. This period of coagulation and intermediate subsidence can be varied to advantage according to the turbidity of the subsided water from about 0.5 to 6 hours, as shown by the results of these investigations.

As the water reaches the filters, it must contain a certain amount of coagulant, either left from a primary application or provided by a secondary application, so that the water may be successfully filtered through American (so called mechanical) filters at a rate from thirty to forty times as fast as in the case of English filters.

Economical Limit to Which the Removal of Suspended Matters Can Be Carried by Plain Subsidence.

Taking into consideration the fact that for a portion of the year the use of coagulants is imperative, the evidence shows that *on an average* plain subsidence can not be economically carried beyond about 24 hours, when viewed from a theoretical and absolute standpoint. The reason of this is that the removal of suspended matters effected by plain subsidence beyond this period can be more economically accomplished by the use of coagulants.

However, from a practical point of view, it is necessary to consider other factors in connection with the best period to provide for plain subsidence. At times of very muddy water in the river, the removal during the second day of plain subsidence would be very considerable. This would be of value in reducing the amount of required coagulant, and in maintaining a safe margin against the passage of undecomposed chemical into the filtered water. It would also permit, by virtue of the storage capacity of the subsiding reservoirs, the stopping of the river water pumps for a day or more at a time when the river water was most difficult and expensive to purify. Further, the mixing of the water in the reservoirs of this size should eliminate in a measure the variability in the composition of the water.

During all times of very turbid water, a period of 48 hours for plain subsidence would be a marked advantage in the management of a purification plant. This is because it would allow advantage to be taken of analytical evidence as to the character of the water and the best way of treating it with chemicals in the American system; and in the modified English system it would insure the removal of coagulated clay with moderate applications of chemical, and thus avoid clogging the filters unnecessarily on the one hand, and a needlessly large amount of chemical on the other.

Taking into consideration the evidence from these tests, it appears that it would be an advantage to provide for an average period of about 48 hours of plain subsidence. Beyond this period it would not be wise to go, except in so far as convenience and economy in construction and reasonable provisions for the future would warrant.

Comparative Difficulties in the Management of Purification Plants by the Two Methods

Owing to the great variability in the composition of the Ohio River water at Cincinnati, it is not an easy matter to manage a large plant in an economical and efficient manner, and both safety and economy demand that the management of a plant, independent of the method adopted, should be in the hands of men thoroughly familiar with this line of work.

Relative to the comparative difficulties in the management of plants of the two methods under consideration at times of muddy water, the evidence shows that the American system would be materially easier to handle. There are a number of reasons for this, among which are the following:

1 — It is less difficult to adjust the proper amount of coagulating chemical to the subsided water than to the much more variable river water.

2 — If the amount of applied chemicals should happen to be too low, there is an opportunity of correcting this promptly and satisfactorily in the American method, by a secondary application at or near the filters; whereas this procedure, if needed, is impossible in the other method, because the chemical would quickly clog the filter.

To provide an ample margin in the application of chemicals in the modified English method to prevent, uniformly, the occurrence of "under-treatment" would be prohibitive, on the ground of cost alone.

3 — There would be experienced more or less difficulties in scraping English filters at times during winter weather, as was actually the case with filter No. 13, due to the formation of ice and the danger of freezing the sand layer, in the case of English filters without covers; and it is not unlikely that ultimately it would be found more advantageous to cover the filters, rather than allow the cold weather to reduce the net capacity of the filters to materially less than the rated capacity.

Comparison of the Qualitative Efficiency of the Two Methods.

Making the necessary assumption that both plants would be well managed, the evidence shows that the bacterial efficiency of the modified English system would probably be slightly greater at times than with the other method. On the basis of annual averages, the difference would be almost inappreciable, and in each case the removal would amount to more than 99 per cent of the river water bacteria. In neither case would the filters be germ proof, although, practically speaking, they would be very nearly so, if they were well managed.

In the removal of the organic matter and clay, both methods give perfectly satisfactory results.

Final Conclusion.

The evidence obtained during these investigations shows that it is practicable to clarify and purify the Ohio River water in a satisfactory manner by either the modified English system or by the American system. Of these two systems, the experience and data indicate clearly that the American system would be the less difficult to operate; would be somewhat cheaper; would give substantially the same satisfactory quality of filtered water, and could be much more readily and cheaply enlarged for future requirement. It is therefore considered that the American system of clarification and purification would be the more advantageous to adopt for the local water supply.

APPENDIX C

Containing brief extracts from the reports of Mr. J. W. Ellms, Chemist, on the results of various experiments and tests made at the laboratory from May, 1903, to September, 1905, to develop and determine upon the various features constituting the best design of a filter which will produce the required results with the simplest form and greatest economy in operation.

The experiments covered a wide range, revealing some curious effects and adding much valuable information in connection with the subject of mechanical filtration. The extracts presented refer only to those experiments which led to the adoption of the design and method of operation here employed.

The first experiments were made with the various strainers on the market and with mechanical agitation, by a rotating rake, of the sand during the period of washing, for the purpose of ascertaining whether any sand passed through the strainers when these were covered by a 7-inch layer of graded gravel, whether the gravel layer was disturbed during washing, and how far the sand worked down into the gravel. With a rate of wash-water velocity not exceeding 12 inches per minute, the layer of gravel was displaced largely by the action of the rake and the sand pocketed between the strainers, and worked down for a distance of 5 to 6 inches into the gravel. Very little sand escaped through the strainers. With this rate of wash water the surface velocity of the water toward the run-off weir was too slow to carry off the sediment, and an excess amount of wash water was necessary to complete the washing.

As it was impossible to observe the effect of the wash water or air upon the sand and gravel a filter 62 inches high was constructed, the four sides of which for a height of 46 inches consisted of glass panels. Both collection and air pipes were placed upon the floor of the filter and various strainers and air nozzles were used during the experiments, to which the following extracts refer.

SEPTEMBER 4, 1903.

"A careful calibration of the air compressor was first made with the modified air nozzles in position, in order to test the uniformity of flow of the air and of the pressures obtained in the delivery of varying volumes of air. It was found that at a gauge pressure of 3 pounds per square inch in the air reservoir and with a static head of 1.47 pounds per square inch, that 7.17 cubic feet of air were delivered per minute. This practically agreed with the calculated volume (7.1 cubic feet per minute) of air which should be delivered under the above conditions."

"Experiments made to determine the excess of pressure over the static head required to clear the air pipes of water after purposely filling them, showed that at least 0.3 pounds per square inch was required. This pressure is greater than when the pipes were free from water, and indicates a greater frictional resistance to the passage of the air over the water."

"With the air pipes free from water, it was found that 0.25 pounds per square inch pressure in excess of the static head was able to maintain a uniform flow of air. In this case a volume of air equal to 1.15 cubic feet per square foot of sand area was being discharged under a gauge pressure of 1.72 pounds per square inch against a static head of 1.47 pounds. This 0.25 pounds excess of pressure, of course, measures the head required to produce the flow of air plus that needed to

overcome the frictional resistance of the system. It was found later that 0.21 pounds per square inch was required to produce the flow of the air and .04 pounds to overcome the friction."

"In all the above experiments the filter only had water in it, the gravel and sand not then having been put in place."

"A series of tables were compiled from quite a large number of observations made during experiments with the air compressor in pumping air into the filters, first through 41 inches of water, second, through gravel and sand and water, and, third, through gravel, sand and water while the latter was passing upward at a definite rate."

"The surprising feature of these results is perhaps the great increase in friction when air and water pass up through the gravel and sand and water at the same time. When air and water pass up at the same time the bed of sand is in a much more fluid state than it is when no water is rising."

"The next point studied was the effect of the air and water currents on a 7-inch layer of graded gravel which had some 34 inches of water standing over it."

"The sudden application of water under a head of 16 feet did not seem to disturb the gravel. The continuous flow of water for some 10 minutes starting at a pressure of 5.07 pounds per square inch, and dropping to a pressure of 3.72 pounds, did not appear to move the gravel about in the least."

"When air alone was blown up through the gravel, however, it was found that under a gauge pressure as low as 2.25 pounds per square inch and a volume of air equivalent to 4.66 cubic feet per minute, that the gravel was slowly moved from one side of the filter to the other. In a short time the gravel became heaped up on one side and a corresponding depression occurred on the other side. This depression lay over the row of air nozzles nearest the air reservoir, and they appeared to rob the other rows of a portion of their air. This is somewhat surprising in view of the fact that with no gravel in the filter an extremely uniform discharge of air took place from all the nozzles, irrespective of position, under the lowest pressures we could apply."

"The gravel appeared to diminish the velocity with which the air left the nozzles considerably, and under low pressure the air appeared to rise simply from its lower specific gravity, except in those spots where the thickness of the gravel had been diminished by being thrown to one side. Under high pressures this phenomenon was much less marked."

"On top of the releveled layer of gravel a 30-inch layer of sand was placed, and the effect of air and water currents observed. Water admitted under a pressure of 5 pounds per square inch had no very marked effect on the gravel. The sand simply became less dense and floated up a little, as has been observed before."

"Air was then forced in through the gravel and sand, the water being shut off. Under a gauge pressure of about 3 pounds a volume of air was discharged into the filter equal to 6.86 cubic feet. The agitation of the sand was less marked than the writer expected, and other observers, when first seeing the effect of the air agitation have noted this fact with considerable surprise. By watching the water above the sand it would be concluded that a very general agitation of the sand was taking place."

"A peculiar effect of the air current was that beside an ascending current moving more or less sand with it, a descending current would often be noticed carrying sand in the opposite direction. This peculiarity is much more marked when air and water are being applied than with the air alone. The gravel was more or less disturbed by the rising air currents."

"Forcing in air and water together was next tried. It was immediately apparent that a far better agitation of the sand took place when the two were applied together. The less dense con-

dition of the sand afforded a better play of the air currents, and they moved the sand about much more easily. Ascending and descending currents of sand could easily be traced. The gravel naturally suffered a great deal in the more violent agitation. At the end of the wash the sand and gravel were more or less mixed up, and presented a very irregular outline. It was quite apparent that the gravel layer ought not to be subjected to the violent action of the air current if it was to retain its uniform distribution over the bottom of the filter, unless it was held in place in some manner."

"An experiment was tried to learn whether it was possible to effect a separation of the sand and gravel into two regular layers by the injection of a large volume of water under considerable velocity. No complete or regular separation of the gravel from sand was effected. The upward motion of the sand was more uniform than at low rates, and fewer counter-currents passing downward were noticed. The greatest force of the upward currents was immediately over the individual strainers. The deposition of the gravel occurred in the less agitated areas."

"Air forced in with the water caused the gravel to settle out at first. But a mixing action of the sand and gravel soon became apparent under the violent agitation produced, and in one place the sand worked its way down to the floor of the filter."

"About the only conclusion which can be drawn from this experiment is that when water is forced from strainers placed at intervals over the floor of the filter, and passed up through a gravel and sand layer, its action is not uniform. Ascending currents of water seeking the paths of least resistance form channels through the semi-fluid mass. This leaves less disturbed areas into which the water currents throw the gravel and sand, and cause them to accumulate. The stronger the water current the better the separation of the gravel from the sand, but no complete and regular separation can be expected so long as the upward motion of the water is not uniform over the whole bottom, both in velocity and direction."

"A series of observations on the increase in volume of the water when air is blown into a filter in varying volumes was made. As the volume of air was increased the increase in the volume of the water was noticed, and it was found to be fairly uniform and practically proportional to the volume of the air forced in. From a number of observations it was found that the vertical rise in the water was .019 of a foot for each cubic foot of air blown in per minute per square foot of filter area."

OCTOBER 7, 1903.

"A number of experiments were undertaken in placing a screen over the gravel layer to prevent the displacement of the gravel."

"Common iron wire cloth was used in these experiments, having 10 meshes to the linear inch."

"The filter has been washed eight or ten times since the screen was put in place, and nothing has thus far been seen which indicates that the gravel layer is in the least disturbed. Air applied at as high a rate as 5.2 cubic feet per minute per square foot of sand area did not displace the gravel layer. Water under a pressure of 5 pounds per square inch failed to disturb the gravel. In the application of air and water together, under considerable pressure, there was no disturbance of the gravel."

"It was thought at first that the cloth might produce an appreciable amount of additional frictional resistance to the passage of the water during filtration, but thus far the initial losses of head with a clean filter have been no greater for the rate of filtration employed than when the screens were not used."

"The application of air and water together in washing this filter was found at the beginning of these experiments to be particularly effective in loosening the sand bed and in agitating the sand in such a manner as to thoroughly clean them of adhering clay particles. It was soon discovered,

however, that sand was carried over into the waste trough in considerable quantities with a volume of air equal to 2.77 cubic feet per minute per square foot of sand area. The weir in this filter is only 15.5 inches above the sand line, and it was thought that by increasing the height this difficulty could be avoided. Accordingly the weir was built up to a height of 24.5 inches above the sand line, but still sand came over, although in much less quantity. The weir was then raised to a little over 30 inches above the sand line, but this by no means prevented some sand getting over into the gutter. It was found that with a volume of air equivalent to 1.4 cubic feet per minute per square foot of sand area and with a water pressure of from 4 to 5 pounds per square inch, that sand was carried over the top of the weir, which, as above stated, was 30 inches above the sand. When air was applied at a rate of 3.5 cubic feet per minute the loss of sand was very great."

"It seems as though this method of washing and agitating the sand bed was not practicable. During these experiments it was apparent that even if it were practicable to apply air and water together, that it was better to allow the air and water to pass in together for about three minutes and then to shut off the air and finish the wash with water alone."

"In applying air without the water at the beginning of the wash, the fact was noted that as the water is drawn down to 5 inches or 6 inches above the sand line, which at present is about 37 inches above the floor of the filter, and the air is applied, a settlement begins in the sand until it is lowered from 1 inch to 1¾ inches below its original level."

"In operating this filter it has always been found that the sand does not get dirty below 2.5 to 3 inches below the surface, and that probably 95 per cent of the sediment is in the upper half-inch. The application of air without the water very effectually breaks up the surface scum, and within a minute or two probably places the greater part of the mud in the 5 or 6 inches of water standing above the top of the sand. By immediately following the application of the air with the water the sand is pretty thoroughly cleaned. The only feature of this process which seems to cast any doubt on the efficiency of this method of cleaning the sand bed is that as soon as the air is cut off and the water is turned on and begins to pass upward through the bed, sand moves from the bottom of the filter to the top and from the top toward the bottom, upward and downward currents being distinctly visible."

DECEMBER 9, 1903.

"In order to learn whether perforated pipe could not be employed for the air and water systems in place of brass nozzles, two coils of 1½-inch perforated brass pipe were used, one being connected to the water system and the other to the air reservoir. The air pipe was perforated on the under side and the water pipe on the upper side of the pipe, with holes $\frac{1}{16}$-inch in diameter."

"In order to study the effect of washing the sand at much higher rate of application of the wash water that could be obtained with the head of water available in the tanks placed in the attic of the laboratory, two 150-gallon tanks, connected together, were placed on the hillside back of the laboratory. The elevation of the bottom of these tanks is about 40 feet above the floor of the filter."

"Experiments made before placing the sand in the filter showed that the air-pipe system delivered air uniformly. If anything, a better distribution of air was obtained than with nozzles."

"The water-strainer system was on the whole fairly satisfactory. Somewhat more water escaped at the end of the pipe nearest the supply pipe than at the dead end of the pipe."

"In the first series of runs of the filter after the modified air and strainer systems had been installed, the sand was first agitated in the usual way by injecting air. Water was then applied at a rate of about 3 cubic feet per square foot per minute for two minutes. During the application of water at this rate, the gauge showed a pressure of about 13.25 pounds per square inch."

"A second series of runs, applying water for three minutes at the rate of 2 cubic feet per square foot per minute have also been made. The pressure used was from 7 to 7.5 pounds per square inch. At this rate excellent results have also been obtained. With a distance of only 14 inches or 15 inches between the sand line and the edge of the gutter, only a very little sand is thrown over. The agitation of the sand is very good and appears to be ample to clean the sand grains."

"The following conclusions appear to be justified by the experimental work:

1 — That the sand is effectively cleaned of the clay and silt characteristic of the Ohio River water by the application of wash water at rates of from 2 to 3 cubic feet per square foot per minute.

2 — That the application of wash water at such a rate in filters using a gravel layer over the strainer system is rendered practicable by placing a screen over the gravel layer.

3 — That the agitation produced is more effective than when air is applied alone to the sand.

4 — That so far as can be observed when air is applied alone, its agitating effect is confined almost entirely to the immediate surface of the sand, the body of the sand not being moved to any extent after the first minute, even with the application of large volumes of air.

5 — That in washing with water alone the sand bed is quickly and thoroughly cleaned, but that the most time and the greater proportion of the volume of water used is required to displace the dirty water above the sand bed; and that therein lies the chief difficulty in washing the filter.

6 — That the mixing action, whereby dirty sand is carried downward toward the gravel layer is to quite an extent prevented by applying the wash water at first at a rate of from 0.5 to 0.75 cubic feet per square foot per minute for about one minute, after which the wash water may be applied at the rate of 2 to 3 cubic feet per square foot per minute for 2.5 to 3 minutes.

7 — That the gutters to carry away the dirty wash water should be placed as close as possible to the sand line without being so low as to permit of sand being thrown over them.

8 — That the present evidence seems to indicate that at a rate of 3 cubic feet per square foot per minute the gutters will have to be placed at least 30 inches above the sand line and possibly 36 inches.

FEBRUARY 1, 1904.

"The crushed quartz which had been in the filter was removed on December 9, 1903, and a layer of Ohio River Sand about 31 inches in depth substituted. This sand was found by a previous analysis to have had an effective size of 0.33 mm. and a uniformity coefficient of 2.0. A few preliminary experiments were made to approximately fix the height of the edge of the gutter above the sand, and in consequence the edge of the gutter was raised to about 31 inches above the sand line. It was soon found in these preliminary washes that the finest portion of the sand was thrown to the top of the sand layer. An analysis of the sand in the top layer showed it to have an effective size of 0.29 mm. and a uniformity coefficient of 1.35."

"A number of different devices were first tried in order to be sure that all of the sand passing over the edge of the gutter was caught before the waste water passed into the sewer."

"Nine or ten runs of the filter were made washing the sand at the end of the run at the average rate of 3.03 cubic feet per square foot per minute. The sand thrown out of the filter during this series of runs measured 117 cubic inches. The volume of sand thrown out represents practically 1.04 per cent of the volume of the sand in the filter. The loss of sand appeared to be progressing uniformly at each wash."

"The fine sand thrown out of the filter in the previous runs was replaced, and twelve more runs were made. The average rate of application of the wash water was 2.54 cubic feet per square foot per minute. The amount of sand thrown out of the filter found in the waste tank measured 7.75 cubic inches. This amount corresponds to .069 per cent of a volume of sand 30 inches deep, having the area of the filter."

"Eleven runs were made in which wash water was applied at an average rate of 2.1 cubic feet per square foot per minute. The sand found in the waste tank measured 2.75 cubic inches. This represents .024 per cent of the volume of the sand in the filter."

"It was the practice in these experiments to apply the wash water for the first half-minute at a rate of .75 to 1.0 cubic feet per square foot per minute. The wash water at the full rate was then immediately applied for the remaining 1.5 to 2.5 minutes, according to the volume of wash water being used."

"The following conclusions appear to be justified as the result of this series of experiments:

1 — That the application of wash water to a filtering bed composed of Ohio River sand, having an effective size of 0.33 mm., at the rate of 2.0 cubic feet per square foot per minute, produces an effective and satisfactory agitation of the sand.

2 — That the application of wash water at this rate thoroughly cleans the sand bed of any clay that may have been carried down into it.

3 — That sand is carried over the edge of a gutter 31 inches above the sand line in too large quantities when the wash water is applied at a rate of over 2.5 cubic feet per square foot per minute.

4 — That at a rate of 2.5 cubic feet per square foot per minute a small amount of sand is carried over a gutter 31 inches above the sand line, but that the amount is probably negligible.

5 — That over 96 per cent of the sand carried over a gutter 31 inches above the sand line at a rate of 2.0 cubic feet per square foot per minute is less than 0.45 mm. in diameter.

6 — That a distance of 30 inches between the sand line and the edge of the gutter will probably prevent the loss of appreciable amounts of sand, when the wash water is applied at rates of less than 2.5 cubic feet per square foot per minute."

MARCH 1, 1904.

"The following experiments were made in order to determine the uniformity of flow and of pressure of water passing through a brass pipe perforated with holes $\frac{1}{16}$ inch in diameter.

"The apparatus consisted of a brass pipe 1.56 inches internal diameter (nominal diameter 1½-inch) and 12 feet in length. Three rows of holes $\frac{1}{16}$ inch in diameter were drilled through the brass pipe. The rows of holes were ½-inch apart, and the holes in each row were spaced ½-inch from center to center."

"Water at a rate of 15 cubic feet per minute was passed through the meter and pipe. This volume of water corresponds to a rate of 2.5 cubic feet per square foot of filtering area per minute. The pressure on the end of the brass pipe was 3.5 pounds per square inch. The jets of water rose to a height of about 4 feet, and were notably uniform with the exception of being a trifle lower at the ends. After running a few minutes the pressure arose to about 4 pounds, and remained there for some time.

"Another trial was made by passing the water through the meter at the rate of 18 cubic feet per minute. This corresponds to a rate of 3 cubic feet per square foot of filtering area per minute. The pressure was 7.5 pounds per square inch at the end of the brass pipe. The jets of water rose to a height of about 8 feet, except for a distance of 12 inches or 14 inches at the ends, where they fell short about one foot. After running about 5 minutes at this rate the pressure rose to 9 pounds per square inch. This was due to the increased number of holes that became closed up, as could plainly be observed.

A third trial was made in which the water was made to pass through the meter at the rate of 12 cubic feet per minute. This corresponds to a rate of 2 cubic feet per square foot of filtering area per minute. The pressure at the end of the brass pipe was 4.5 pounds per square inch. The reason

that this pressure at a rate of 12 cubic feet per minute is higher than for that observed for a rate of 15 cubic feet per minute (3.5 pounds) was evidently the result of the closing of the holes in the strainer pipe. This conclusion is not a matter of inference for the increased number of holes in the strainer pipe which were either not throwing water at all or only throwing it in limited quantities, could be plainly observed.

"A head of water of 40 feet in the wash-water tanks would, therefore, appear to furnish sufficient pressure to supply the wash water at a rate as high as even 3 cubic feet per square foot of filtering area per minute, provided the loss of head in the piping system is no greater, which does not seem probable, as nothing but filtered water would pass through them."

SEPTEMBER 22, 1904.

"After cleaning out the strainer system the filter was again put into operation on August 4th. The river water was quite clear, and had been so for perhaps two weeks. The filter was started, but ran only 2 1-6 hours, during which time the loss of head increased from 1.45 feet at the start to 12.05 feet at the end of this period. Only about one-half grain of sulphate of aluminum per gallon had been used. The reason for the very short period of service, considering the clearness of the applied water, was by no means apparent. It was at first thought that some obstruction in the pipe line was the cause of the difficulty. But after a careful examination it was found that this could not be the cause for the filter acting in this peculiar manner.

"The filter was thoroughly washed and again started. It ran for only 1 7-12 hours. The initial loss of head was 1.65 feet, and the final loss of head 12.25 feet. The effect of a much larger quantity of aluminum sulphate (2.7 grains per gallon) was tried on this run, but it did not appear to have any great effect on the period of service. On August 5th the filter was again started, and only ran for one hour, the loss of head at the start being 1.7 feet and at the end of the run 12.25 feet. The subsiding basins were then washed out to be sure that it was not accumulated sediment which was being carried over on to the filter from these settling barrels. The filter was again started, but no aluminum sulphate was used. The filter ran 1 hour and 35 minutes, and the loss of head at the start was 1.7 feet, and at the end of the period 12.05 feet.

"After numerous attempts to locate the cause for the rapid loss of head a microscopical examination of the sand and of the water above the sand was made, and at once revealed the presence of a considerable number of diatoms. They consisted almost entirely of the genera Synedra, and of the species Synedra ulna.

It was not at first though possible that these diatoms were the cause of the clogging of the sand layer. But a careful examination of the sand microscopically at the close of a period of filtration showed the organisms to be present in large numbers laced in between the sand grains, and forming a mat at and near the surface of the sand. The small amount of clay in the water in all probability assisted in the formation of a more impervious mat, but it became quite clear that the principal cause lay in the organisms themselves.

"The micro-organism Synedra ulna is a long, rectilinear shaped diatom. It is, when well developed, about .0055 of an inch in length and .0003 of an inch in width, and possibly a little less than .0003 of an inch in thickness. Calculating the surface area of these organisms, when laid flat, showing the so-called girdle view of the organism, to be .000001 of a square inch, it can be readily shown that with a sufficient number present they could easily clog the surface of the sand, when the volume of water passing on to the filter had become great enough. When the high rate at which water passes through a mechanical filter is considered, it can be easily conceived that the time required to cover the surface of the sand with these organisms is not very great. When filtering at a rate of 125 million gallons per acre daily, this experimental filter must pass over 40 cubic feet

of water per hour. On the supposition that each cubic centimeter of the applied water contained 200 of these diatoms, and that in the course of an hour 40 cubic feet of water were applied to the same, then 227,100,000 diatoms would be deposited on the surface of the sand. Assuming that they have an average area of .000001 of a square inch, then they would cover 227 square inches of the 370 square inches composing the total area of the sand. This is over 60 per cent of the sand surface.

"As soon as the significance of these facts were appreciated, numerical counts of the diatoms present in the applied water were made, which was found to contain from 250 to 300 (approximate) diatoms per cubic centimeter. Water applied to the filter on August 11 showed about the same number. From this date on microscopical examinations of the applied water and occasionally of the reservoir water were made until August 26, when the organism practically disappeared."

The following tables are a compilation of the results of the large number of experiments made, and are comparable only as the rate of applied wash water could not be regulated with absolute uniformity. They indicate, however, the resistance offered by the different portions of the proposed filter system.

"A series of experiments were made to determine the effect of the size of the opening in the wire screen used to retain the gravel layer in position over the strainer system at the pressure required to wash the filter. Considerable other data were also obtained bearing upon the friction head produced by the strainers, gravel, and sand. The results given in the following tables are averages of 179 readings of the water meter and the mercury pressure gauge used to measure the head required to produce the several rates of flow."

"The strainer system employed consisted of a brass plate $\frac{1}{16}$-inch in thickness and 3½ inches wide. It was curved to a radius of 4½ inches, and the edges were flattened. The chord of the curved surface was 2¾ inches in length, and the edges were ⅜-inch in width. The plate was perforated with holes 3-32-inch in diameter, spaced ¾-inch apart, the rows being placed lengthwise of the plate, and were 11-16-inch apart. The plate contained 62 holes for each square foot of the filter area which it served."

"Trough-shaped wooden forms were also made in accordance with the design of the floor of the proposed filters. The channel in the bottom of the forms, which was rectangular in section, and had a depth of 2 inches and a width of 2¾ inches, was covered with the curved strainer plates.

"The forms above the strainer plates were filled with gravel in layers of the following depths:

Size of Gravel	Depth of Layer
From ½ in. to 1 in. in diameter	1 inch
" ¼ in. to ½ in. in diameter	1 "
" ⅛ in. to ¼ in. in diameter	2 "
" $\frac{1}{16}$ in. to ⅛ in. in diameter	4 "

"Two sizes of brass wire cloth for the gravel screen were experimented with, one having 16 meshes per linear inch, woven with a No. 27 wire, and having an opening of .046 inch and a screen having 12 meshes per linear inch woven with a No. 25 wire, having an opening of .063-inch. The screen was tacked to the edges of the wooden forms above the gravel layer."

"Thirty inches of river sand were placed on top of the gravel screen. The sand had probably an effective size of about .37 to .40 mm. and a uniformity coefficient of 1.4 to 1.5. River water, which during these experiments was quite clear, was used in making the tests."

"The plan followed in making these experiments was to determine the pressure required to produce a flow of water up through the piping and strainer system at rates of approximately 2.0, 2.5,

and 3.0 cubic feet per minute per square foot of filtering area. The pressure required to overcome the resistance of the piping system and strainer plates was first determined. The brass wire screen was then introduced, and the increased pressure which it produced was next found. The gravel layer and the sand layer were successively placed in the filter, and the increased pressure resulting from each of these factors was obtained. The static head against which the water was discharged (5.7 feet) was practically a constant factor in all of these experiments."

TABLE I.

Approximate rate of 2.0 cubic feet per minute per square foot.

	Head Required in Feet	Rate of Wash Water	Head Required in Feet	Rate of Wash Water
Static head from strainer top to gutter edge	5.70	.....	5.70	.....
Pressure head at holes in strainer plate	3.50	2.04	3.50	2.04
Head required for screen (.063")	0.21	2.14	2.31*	2.25*
Head required for gravel	1.61	2.14		
Head required for sand	1.58	2.06	2.05*	2.08*
Total Head	12.60		13.56	

TABLE II.

Approximate rate of 2.5 cubic feet per minute per square foot.

	Head Required in Feet	Rate of Wash Water	Head Required in Feet	Rate of Wash Water
Static head from strainer top to gutter edge	5.70	.....	5.70	.....
Pressure head at holes in strainer plate	5.39	2.53	5.39	2.53
Head required for screen (.063")	0.12	2.54	2.81*	2.58*
Head required for gravel	1.72	2.45		
Head required for sand	2.61	2.54	2.54*	2 52*
Total Head	15.54		16.44	

TABLE III.

Approximate rate of 3.0 cubic feet per minute per square foot.

	Head Required in Feet	Rate of Wash Water	Head Required in Feet	Rate of Wash Water
Static head from strainer top to gutter edge	5 70	.....	5.70	.....
Pressure head on holes in strainer plate	7.51	3.00	7.51	3.00
Head required for screen (.063")	0.35	3.00	3.14*	2.93*
Head required for gravel	2.15	3.06		
Head required for sand	2.20	2.96	2.33*	2.89*
Total Head	17.91		18.68	

"These experiments indicate that it is advantageous to have as large a mesh screen as possible without allowing the passage of the gravel. No evidence of the screen being clogged by gravel sticking in the meshes was noticed. The pressures required for washing agree generally with those obtained during the operation of the filter during the past two years."

*These tests made with screen 0.046".

APPENDIX D

PROPERTY AND RIGHT-OF-WAY ACQUIRED

No.	Grantor	Date of Conveyance	Consideration	Kind of Conveyance	Acres	Location and Purpose
1	Ebersole estate	April, 1898	48,026 00	Condemned	156.630	Land adjoining California for Pumping Station, Settling Reservoirs, Filter Plant, etc.
2	Henry Fahrenkamp	April, 1898	23,500 00	"	81.340	
3	Mary Tice	April, 1898	3,000 00	"	13.520	
4	Anthony Squires	April, 1898	4,500 00	"	14.460	
5	Harriet B. Johnston	April, 1898	5,000 00	"	12.155	
6	Blanche B. Hart	April, 1898	4,701 50	"	18.806	
7	Antoinette Shaw	April, 1898	815 00	"	2.198	
8	John Mears (guardian)	April, 1898	1.500 00	"	6.628	
9	Celina M. Ebersole et al	Sep. 28, 1898	*	Warranty deed	20.250	
10	G. W. C. Johnston	Oct. 17, 1898		Special war'nty deed		Easement over road.
11	Columbia & New Richmond Turnpike and Bridge Co.	May 31, 1898	9.000 00	Warranty deed		That part of grantor's turnpike from toll-gate at Salem Pike to schoolhouse at California.
12	John Pharo	Aug. 26, 1898	10,000 00	Condemned	7.930	Land for Main Pumping Station, Eastern Avenue.
13	Aaron Torrence	Aug. 26, 1898	12,000 00	"		
14	John F. Torrence	Aug. 26, 1898	6,600 00	"		
15	Nancy B. Torrence	Aug. 26, 1898	5,400 00	"		
16	City of Covington	Jan. 27, 1899	3,500 00	Warranty deed	0.308	50-foot lot on Kentucky side.
17	Samuel W. Hills	Mar. 22, 1899	9,375 00	"	11.407	One-half interest each in Walmer property on Kentucky side.
18	Ella Fields	Mar. 28, 1899	9,375 00	"		
19	W. W. Helm (State of Kentucky.)	Mar. 29, 1899	2,500 00	Special war'nty deed	10.00	Land in river bed opposite California.
20	Lizzie B. Hewitt	Dec. 19, 1899	4,369 97	Warranty deed	†15.000	
21	Louis H. Meyer	Feb. 17, 1900	300 00	"	2.249	
22	Caroline Hartlaub	Feb. 19, 1900	1,150 00	"	2.892	
23	‡Philip Hartlaub	Feb. 19, 1900		"		Right-of-way and property on line of gravity conduit.
24	‡Wm. Henry Elder	Mar. 1, 1900		"		
25	John Hartlaub	Feb. 19, 1900	1,200 00	"	0.897	
26	Warner Eversull	Dec. 21, 1899	475 00	"	1.079	

*Consideration included in No. 1. †Approximated. ‡Interest in next above. §Second deed given to correct error of first.

PROPERTY AND RIGHT-OF-WAY ACQUIRED—Continued

No.	Grantor	Date of Conveyance	Consideration	Kind of Conveyance	Acres	Location and Purpose
27	Commissioners of Hamilton County	Dec. 27, 1899	500 00	Warranty deed		Right-of-way for conduit under C. & N. R. Turnpike.
28	Amanda Stump	Jan. 24, 1900	1,500 00	"	0.609	Property on conduit line, on Congress Avenue and Taylor Street.
29	C. C. Archer	Jan. 15, 1900	500 00	"	0.427	
30	Elizabeth Garrett	Feb. 26, 1900	1,200 00	"	1.169	
31	Cincinnati Gymnasium and Athletic Club	July 10, 1900	541 00	"		Right-of-way for conduit.
32	Geo. W. Lewis et al	June 27, 1900	900 00	"		
33	Geo. W. Lewis et al	§Oct. 18, 1900		"		
34	Cincinnati Gas Light and Coke Co.	Nov. 23, 1900	1,000 00	License		Right-of-way for conduit.
35	Dorothea Bohmer	Aug. 14, 1900	150 00	Warranty deed		Right-of-way for conduit.
36	David K. Innes	July 12, 1900	250 00	"		
37	Michael Duffy	July 2, 1900	125 00	"		
38	Michael Duffy	§Oct. 18, 1900		"		
39	Henry Rering	July 6, 1900	125 00	"		
40	Henry Rering	§Oct. 24, 1900		"		
41	Bernard Flamm	July 9, 1900	125 00	"		
42	Bernard Flamm	§Oct. 19, 1900		"		
43	Michael Linskey	July 3, 1900	150 00	"		
44	Michael Linskey	§Oct. 18, 1900		"		
45	Michael Molloney	July 6, 1900	300 00	"		
46	Michael Molloney	§Oct. 19, 1900		"		
47	Harriet B. Stewart et al	June 21, 1900	1,000 00	"		
48	Harriet B. Stewart et al	§Oct. 19, 1900		"		
49	T. F. Dickerson	May 8, 1901	4,000 00	"		Lot on line of high-service main
50	John H. Schnehain et al	May 16, 1901	300 00	"		Lot on line of high-service main.
51	Milton Ebersole et al	Sept. 2, 1901	3,000 00	"	6.845	Lot at California for borrow pit.
52	Milton Ebersole et al	Dec. 27, 1901		"	1.50	30-foot strip for widening C. & N. R. Turnpike from toll-gate to north line of waterworks property, near California.
53	Jacob G. Schmidlapp	Jan. 2, 1902	2,810 00	"	(2.81)	Lot on north side Columbia Ave., for borrow pit for filling site of Main Pumping Station. Purchase price. $8,430. Resold to J. G. Schmidlapp for $5,620.
54	Lucy C. Maloney	April 1, 1902	2,500 00	"	0.08	Lot on south side Columbia Avenue for right of way for incline for filling site of Main Pumping Station.

*Consideration included in No. 1. †Approximated. ‡Interest in next above. §Second deed given to correct error of first.

PROPERTY AND RIGHT-OF-WAY ACQUIRED—Continued

No.	Grantor	Date of Conveyance	Consideration	Kind of Conveyance	Acres	Location and Purpose
55	Caius C. Bragg	Aug. 20, 1902	10,000 00	Warranty deed	5.05	Lot on south side Cushing Street, west of Lumber Street, for borrow pit for filling site of Main Pumping Station.
56	A. S. Ludlow, assignee of Catharine Ranney	Aug. 20, 1904	700 00	Assignee's deed		Two lots on south side of Harrison Avenue, for Western Hills Pumping Station.
57	Rosa Fredericka Bruns	Nov. 22, 1904	4,620 00	Warranty deed		Two lots on south side of Harrison Avenue, and two lots on north side of Queen City Avenue, for Western Hills Pumping Station.
58	Anna Shick	Nov. 28, 1904	5,000 00	"		One lot on north side of Harrison Avenue, for Western Hills Pumping Station.
59	George Wuest	Feb. 1, 1905	4,400 00	"		One lot on north side Queen City Avenue, for Western Hills Pumping Station.
60	Rebecca Barrowcliff and Eliza B. Fulton	April 7, 1905	25 00	"		3-foot strip of lot on south side of Ludlow Avenue at Canal for pipe line.
61	Sidney B. Knowlton, Martha J. Eastman and Martha H. Knowlton	July 28, 1905	108 59	"		5-foot strip of lot on north side Dodsworth Avenue at Mill Creek for pipe line.
62	William J. Breed and Laura A. Breed	Oct. 17, 1905	300 00	"		6-foot strip on south side Queen City Avenue at Mill Creek for pipe line.
63	Peter Henry Pharo and Mary Pharo	July 8, 1908	1,200 00	"		10-foot strip on east side of Triangular lot opposite Main Pumping station for high service pump main.
64	Chesapeake & Ohio Railroad Co	Jan. 8, 1909		Lease		Easement for extending storehouse at west end of intake pier bridge onto C. & O right of way.
	Total		$213,717.06		391.429	

*Consideration included in No. 1. †Approximated. ‡Interest in next above. §Second deed given to correct error of first.

APPENDIX E

Statement of the bonds issued by the Board of Trustees, "Commissioners of Water Works," under the provisions of the Water Works Act of 1896 and the Acts amendatory thereto and by the City of Cincinnati through the City Council in 1908, together with the amounts received therefor, as well as from all other sources up to March 1, 1909. The terms of the bonds are from twenty to forty years.

Date	Sources of Receipts.	Amount of Bonds Issued	Rate of Interest	Premium and accrued interest	Total	Grand Total Received.
Feb. 15, 1897	From Sinking Fund Trustees—Sale of Bonds	$50,000.00	3.65%		$50,000.00	
Oct. 5, 1897	From Sinking Fund Trustees—Sale of Bonds	250,000.00	3.50%		250,000.00	$300,000.00
July 8, 1898	From Sinking Fund Trustees—Sale of Bonds	50,000.000	3.50%		50,000.00	
Aug. 5, 1898	From Atlas National Bank, Western German Bank, R. Kleybolte & Co.—Bonds	500,000.00	3.50%	$18,500.00	518,500.00	568,500.00
Aug. 3, 1899	From Atlas National Bank, Western German Bank, R. Kleybolte & Co.—Bonds	1,000.000.00	3.00%	23,939.00	1,023,939.00	
	Interest on deposits				8,006.91	
	From Rents				821.50	
	From miscellaneous sources, including sale of material				2,192.91	1,034,960.32
1900.	Interest on deposits				18,747.62	
	From Rents				598.00	
	From miscellaneous sources, including sale of material				87.81	19,433.43
Feb. 1, 1901	Atlas National Bank, Western German Bank, R. Kleybolte & Co.—Bonds	1,000,000.00	3.00%	24,039.00	1,024,039.00	
	Interest on deposits				26,801.22	
	From Rents				127.90	
	Toll on cars over viaduct				672.00	
	From miscellaneous sources, including sale of material				370.74	1,052,010.86
Dec. 3, 1902	Sinking Fund Trustees—Sale of Bonds	75.000.00	3.50%		75,000.00	
	Interest received on deposits				15,135.75	
	From Rents				89.00	
	Toll on cars over viaduct				1,244.00	
	From miscellaneous scources, including sale of material				397.50	91,866.25
Feb. 3, 1903	Atlas National Bank—Sale of Bonds	560,000.00	3½%	15,600.00		
Feb. 5, 1903	Atlas National Bank—Sale of Bonds	440,000.00	3½%			
Aug. 5, 1903	Atlas National Bank and Market National Bank—Sale of Bonds	500,000.00	3½%		1,515,600.00	
	Interest on deposits				14,187.61	
	From rents				90.00	
	Toll on cars over viaduct				540.00	
	Lane & Bodley Co.—Settlement Contract No. 5				65,000.00	
	Sale of 2.81 acres land on Columbia Ave.				5,620.00	
	From miscellaneous sources, including sale of material				33.89	1,601,071.50
						4,667,842.36

Date	Source of Receipts.	Amount of Bonds Issued	Rate of Interest	Premium and accrued interest	Total	Grand Total Received
						$4,667,842.36
July 9, 1904	W. R. Todd & Co.—Sale of Bonds	$500,000.00	3.65%			
July 15, 1904	W. R. Todd & Co.—Sale of Bonds	575,000.00	3.65%	$25,065.50	$1,100,065.50	
	Interest on deposits				12,322.45	
	From rents				105.00	
	Toll on cars over viaduct				299.00	
	Sale of material				15.00	
	Refunded by A. F. Nagle and W. N. Stites				612.50	
						1,113,419.45
Feb. 3, 1905	E. H. Rollins & Sons, Chicago—Sale of Bonds	1,000,000.00	3.50%	10,705.00	1,010,705.00	
	Interest on deposits				22,334.70	
	From rents				60.00	
	Toll on cars over viaduct				326.00	
	Refunded by Thos. Maloney for read-vertising bids				159.33	
	Sale of material				267.50	
						1,033,852.53
Jan. 5, 1906	Seasongood & Mayer—Sale of Bonds	500,000.00	3.50%	3,891.00		
July 14, 1906	Sinking Fund Trustees—Sale of Bonds	150,000.00	3.65%			
July 16, 1906	Sinking Fund Trustees—Sale of Bonds	100,000.00	3.65%			
Aug. 8, 1906	Fifth National and City Hall National Banks, Sale of Bonds	80,000.00	3.65%	141.00		
Aug. 9, 1906	Merchants National Bank—Sale of Bonds	50,000.00	3.65%	35.00		
Aug. 10, 1906	Central Trust & Safe Deposit Co., Kuhn & Son, Atlas National Bank—Sale of Bonds	115,000.00	3.65%	92.00		
Sep. 27, 1906	Sinking Fund Trustees—Sale of Bonds	5,000.00	4.00%			
Sep. 27, 1906	First National Bank—Sale of Bonds	1,000,000.00	4.00%	19,843.78		
					$2,024,002.78	
	Interest on deposits				11,023.18	
	From rents				100.00	
	Toll on cars over viaduct				1,104.00	
	From miscellaneous sources				126.90	
						2,036,356.86
Feb. 23, 1907	Atlas National Bank et al. Bonds	1,000,000.00	4%			
Aug. 16, 1907	Atlas National Bank et al. Bonds	500,000.00	4%	40,991.12	1,540,991.12	
	Interest on deposits				22,295.40	
	From rents				100.00	
	Toll on cars over viaduct				563.00	
	Sale of materials				289.05	
						1,564,238.57
May 6, 1908	Atlas National Bank—(Sold by City Auditor)	250,000.00	4%	Premium and accrued interest Paid to Sinking Fd. Trustees		
Aug. 1, 1908	Union Savings Bank and Trust Co., (Sold by City Auditor)	500,000.00	4%		750,000.00	
	Interest on deposits				16,486.92	
	Toll on cars over viaduct				1,995.00	
	Fidelity and Guarantee Co.—Settlement Contract, No. 12				1,000.00	
	Settlement in Claim against J. H. Baumer, Contract No. 53				400.00	
	From Miscellaneous sources, including sale of material				235.29	
	From B. P. S. for reimbursement for pumpage				324,040.26	
						1.094,157.47
1909 to March 1st.	Interest on deposits				2,877.65	
	From rents				100.00	
	Sale of materials				113.09	3,090.74
	Total					$11,512,957.98

SUMMARY OF RECEIPTS.

Total amount of bonds issued by the Board of Trustees	$10,000,000.00
Total amount of bonds issued by the City Council	750,000.00
Total amount received as premiums and accrued interest	182,842.40
Received as interest on deposits	170,219.41
Received from rentals	2,191.40
Received as toll on cars over viaduct	6,743.00
Received from Lane & Bodley in settlement of Contract No. 5	65,000.00
Received from Fidelity & Guarantee Co., for settlement of Reservoir Contract No. 12	1,000.00
Received in settlement of claim against J. H. Baumer—Contract No. 53	400.00
Refunded by Thos. Maloney for readvertising bids	159.33
Received from sale of 2. 81 acres land on Columbia Ave	5,620.00
Received from miscellaneous sources—includes sale of material	4,129.68
Refunded by A. F. Nagle and W. N. Stites	612.50
Refunded by B. of P. S. for operation	324,040.26
Total amount received to March 1, 1909	$11,512,957.98
Total amount expended to March 1, 1909	10,844,330.90
	$668,627.08
Amounts due on contracts on completion of work	613,147.32
Balance	$55,479.76
Amount due for operation from Jan. 1 to March 1, 1909	35,966.39
	$91,446.15

The following statement exhibits the amounts expended up to March 1, 1909, distributed among the different classifications of the work, and the amounts which will become due on the completion of unfinished contracts and work.

CLASSIFICATION.	Expended.	Amounts due or to become due.
Commissioners and office salaries	$334,219.34	
Office and sundry admistration expenses	83,927.26	
Legal expenses	34,629.13	
Insurance	1,380.49	
Engineering—preliminary surveys	39,635.43	
Experimental purification plant	41,672.81	
Cleaning Eden Park Reservoir	8,712.75	
Engineering and Inspection—Construction	757,272.73	
Real Estate and Rights of Way	273,771.41	
Intake Pier	178,005.43	
Intake Tunnel and Shafts	64,987.55	
River Pumping Station—Pump Pit, Grading and Buildings	740,507.99	
River Pumping Station—Machinery	767,237.09	$334,031.39
Pump mains to Settling Reservoirs	187,106.53	
Settling Reservoirs	1,418,879.50	96,174.48
Grading of Roads and Grounds including culverts and viaduct	209,837.22	
Pipe Lines from Settling Reservoits to Filter Plant	55,354.77	
Coagulation basins including Piping	331,730.09	
Filters, including Buildings and Piping	724,572.62	13,883.71
Clear Water Basin, including Piping	151,064.30	
General Maintenance of Roads and other completed work	4,563.77	
Gravity Tunnel and Shafts	1,013,860.92	
Main Pumping Station—Grading, Pump Pit and Buildings	798,084.35	
Main Pumping Station—Machinery	711,154.62	166,777.36
Low Service Pump Main	341,975.51	
High Service Pumping Main	139,586.14	
Western Hills Pumping Station—Buildings	81,875.73	225.00
Western Hills Pumping Station—Machinery	40,187.20	
Price Hill Pump Main	29,011.14	
Betterment of Distribution System	858,473.56	2,055.38
Operating expenses from January 1, 1907 to March 1, 1909	421,053.52	
Total amount expended to March 1, 1909	$10,844,330.90	$613,147.32
Balance due on completion of work	613,147.32	
Total cost of work	$11,457,478.22	

APPENDIX F

REPORT OF OFFICIAL DUTY AND CAPACITY TRIALS OF THE PUMPING ENGINES AT THE RIVER STATION, NEW WATER WORKS, CINCINNATI, OHIO

The pumping equipment of this station consists of four thirty-million-gallon vertical, triple expansion pumping engines, built by the Camden Iron Works, of Camden, N. J., together with eight 200 H. P. Stirling water-tube boilers set in batteries of two each, with two Green economizers, two Foster superheaters, independent feed pumps, and other auxiliaries. Each engine is equipped with an exhaust heater, surface condenser, attached air pump, air compressor, boiler feed pumps, and bilge pumps. An independent air compressor, Westinghouse make, is also provided. The steam piping is so arranged that either saturated or superheated steam can be used in operating the engines. The steam is delivered to the engine room through one line of 14-inch piping, which branches into two smaller lines inside of the engine room, two engines taking steam from each of these branches. The exhaust steam from the low-pressure cylinder flows through the exhaust heater to the condenser, thence to the air pump, which removes the condensed water and vapor and maintains a vacuum in the condenser.

The water pumped is taken directly from a shaft ten feet in diameter connecting with a tunnel seven feet in diameter and 1,425 feet long, terminating at the Intake Pier near the Kentucky shore. The elevation of the suction valves in the pumps is about 4 feet 4 inches above extreme low water; consequently, except in the case of an unusually low stage in the river, water enters the pump chambers under a static head. The discharge pipe from each pump chamber is 36 inches in diameter, and leads to a discharge header on each engine 48 inches in diameter, which in turn discharges into one or both of two 60-inch mains to the settling reservoirs. In these tests both 60-inch mains were used. The surface condenser on each engine is located in the 48-inch header, the entire discharge passing through it.

Each pumping engine, with its appurtenances, is guaranteed to be capable of delivering 30,000,000 U. S. gallons of water in 24 hours at a piston speed not to exceed 250 feet per minute and at a steam pressure of 150 pounds per square inch at the engine, and to be capable of developing a test duty of 115,000,000 foot pounds of work for every 100 pounds of coal consumed in the boiler furnaces during a continuous run of 144 hours, the stage of the river not to exceed 20 feet above low water.

The principal dimensions of the pumping engines and appurtenances are given below:

Capacity in 24 hours, gallons	30,000,000
Number of steam cylinders	3
Diameter of H. P. cylinder	29″
Diameter of I. P. cylinder	54″
Diameter of L. P. cylinder	82″
Diameter of all piston rods	6¼″
Piston speed, feet per minute	248
Number of revolutions per minute	15½
Normal stroke of pistons	96″
Type of steam valve gear	Corliss & Poppet
Number of re-heaters	2
Surface of tubing in 1st re-heater, sq. ft	122
Surface of tubing in 2nd re-heater, sq. ft	276
Length of main shaft	10′ 2″

Diameter of main shaft	19″
Length of main shaft journals	28″
Diameter of main shaft journals	19″
Length of crank pin journal	10″
Diameter of crank pin journal	H.P.& L.P. 10″ I.P. 14″
Length of cross head pin journal	10″
Diameter cross head pin journal	10″
Number of fly wheels	2
Diameter of fly-wheel	24′
Weight of each fly-wheel	40 tons.
Number of pumps	3
Diameter of main pump plungers	37½″
Normal stroke of plungers	96″
Diameter of pump barrel	54″
Diameter of pump valve chamber	74″
Number of discharge pump valves	840
Number of suction pump valves	840
Diameter of pump valve	3½″
Effective area of pump valves	4393 sq. ft.
Proportion of valve area to plunger area	132.6
Diameter of discharge	48″
Kind of condenser	Surface.
Size of condenser	62″ x 12′ 4-¾″
Condensing surface	2130 sq. ft.
Number of attached air pumps	1
Diameter of attached air pump cylinder	28″
Stroke of attached air pump piston	30″
Number of attached feed pumps	1
Diameter of attached feed pump plunger	2¾″
Stroke of attached feed pump plunger	96″
Number of attached air compressors	1
Diameter of attached air compressor plunger	3⅜″
Stroke of attached air compressor plunger	96″
Number of attached bilge pumps	1
Diameter of attached bilge pump plunger	3″
Stroke of attached bilge pump plunger	96″
Heating surface of exhaust heater	150.5 sq. ft.

The boiler plant is equipped with four batteries, each battery consisting of two Stirling water-tube boilers, equipped with American underfeed stokers. There are two large Green economizers, each arranged to intercept the chimney gases from two batteries. One economizer engine is used to operate the scrapers of both. One stack eight feet in diameter by 175 feet high is provided. Forced draught is supplied by two 8-inch by 10-inch Buffalo Forge Company engines, each driving an 85-inch direct connected Buffalo Forge Company fan. Two auxiliary 10-inch x 6-inch x 10-inch boiler feed pumps, Henry R. Worthington make, are provided, also one auxiliary feed water heater of Berryman type. The exhaust steam from the fan engines, stokers, economizer engine and auxiliary feed pumps is used in this heater to raise the temperature of the feed water just before entering the economizer.

The feed water for the boilers is taken from a hot well, which is supplied with filtered water from the service main, and the condensed jacket steam, the elevation of the water in the well being controlled by an automatic float valve. From here it is forced by the attached feed pump through the exhaust heater, through the auxiliary heater, thence through the economizers and into the boilers.

Each pair of batteries of boilers is equipped with a Foster direct fired superheater, designed to give 100 degrees superheat to the steam. The steam piping is arranged so that either saturated or superheated steam may be delivered to the engine.

The principal dimensions of the boilers and auxiliaries are as follows:

Number of batteries	4
Number of boilers in each battery	2
Number of tubes in each boiler	176
Outside diameter of boiler tubes	3¼″
Number of upper drums	3
Diameter of upper drums	36″
Length of upper drums	10′ 9″
Diameter of mud drum	42″
Length of mud drum	9′ 3″
Total water heating surface each boiler	2,016 sq. ft.
Total H. P. builder's rating, each	201
Length of grate front wall to bridge wall	6′
Width of grate wall to wall	7′
Grate area, square feet	42
Ratio of heating surface to grate surface	48 to 1
Green Economizer—Number of	2
Green Economizer—Number of sections each	40
Green Economizer—Heating surface, sq. ft., each	5,700
Auxiliary heater—H. P.	200
Foster superheaters—Number of	2
Length of grate	6′ 4″
Width of grate	2′ 8″
Number of tubes	60
Heating surface, linear feet corrugated tubing, each	500

Four tests were conducted, consisting of the duty trials of two engines, boilers and auxiliaries with saturated steam and two trials using superheated steam. The duration of each test was 144 hours, the exact time and the numbers of the engines and boilers tested being as follows:

Saturated steam:		
Engine No. 3—Bat. No. 3	11:00 A. M., Sept. 1, 1908	to 11:00 A. M., Sept. 7, 1908.
Engine No. 4—Bat. No. 4	12:00 M. Sept. 16, 1908	to 12:00 M. Sept. 22, 1908.
Superheated steam:		
Engine No. 1—Bat. No. 3	11:00 A. M., Oct. 5, 1908	to 11:00 A. M., Oct. 11, 1908.
Engine No. 3—Bat. No. 4	10:00 A. M., Oct. 27, 1908	to 10:00 A. M., Nov. 2, 1908.

Previous to starting each test all steam and exhaust pipes connecting the machinery under test with other parts of the plant were either disconnected or blanked off. Gauges were carefully calibrated before starting, and all important gauges were again calibrated at the end of each test and corrections applied accordingly. All scales were tested by the City Sealer of Weights and Measures. In the two tests in which the superheater was used the rear half of the grate of the superheater was bricked off, as the superheater was designed with sufficient capacity for two batteries of boilers, while only one battery was used in the test.

The boilers used were carefully examined and cleaned, both inside and out, and all scales removed from the tubes by turbining. The economizer was also cleaned and turbined, and all soot accumulations were removed from the smoke flues and stack.

All parts of the boilers under test were put in good working condition, and all air leaks about the boiler settings were carefully stopped.

Before starting any of the duty trials the representatives of the contractor demanded that allowances be made for a part of the steam furnished the fan engine, for the slate in the coal and also for the moisture in the coal. These allowances were refused by the Commissioners' representative, and have not been considered in calculating the duty of the pumping engines. The contractor's representatives picked the slate from the coal after it had been weighed to the boilers, and a record of the weight and percentage of the slate is incorporated herein. As a matter of information, samples (about 5 pounds) were taken from each car of coal (2,000 pounds) for the determination

of the moisture in the coal. These samples were weighed and then placed over the boilers for 24 hours, after which time they were weighed again. The average percentage of loss from these determinations was taken as the percentage of moisture in the coal. Small samples were also taken from each car of coal for chemical analysis.

Each engine with its boiler and appurtenances was operated under full test conditions for several hours before beginning the official observations. At the time of starting the condition of the fires and the height of the water in the gauge glasses were noted, and the fires and water levels were brought to the same condition at the close of the test.

The coal used was ordinary Pittsburg nut and slack, as furnished in the Cincinnati market. The contractors were given the privilege of using coal from any of the bins at this station, but no allowances of any kind were made for the quality or character of the coal so selected.

All coal delivered to the boilers under test and all ashes removed from the furnaces were carefully weighed. Hourly readings were taken of the various temperatures, draught gauges, etc. Readings of the steam pressure at the boilers were taken every thirty minutes. Observations of the steam pressure at the engines, first and second receiver pressures, jacket steam pressure, vacuum gauge, revolution counter, and suction and discharge water pressures, were taken every fifteen minutes throughout the tests. The temperature of the water pumped was taken every hour. Observations were also taken of the color and duration of the smoke issuing from the stack during the daylight hours of the tests. No smoke was considered which was not of a darker color than that allowed by the city ordinance.

A separate battery of boilers connected to the same stack was operated throughout each test in order to furnish steam for operating the electric machinery. Consequently the smoke as recorded was that made by both batteries of boilers.

The overflow from the attached air pump was weighed for 12 hours each day. As the contractors were entitled to the heat in the jacket trap discharges, the jacket steam was not weighed, but its amount and proportion were taken from preliminary tests made by the contractors.

Tests of a few hours were made during each duty trial to determine the amount of steam used by the economizer, fan and stoker engines. This was determined approximately by weighing the drainage from the auxiliary heater.

The duty per 1,000 pounds of dry steam, as calculated and given herein for the first three tests is based upon the observation of the 72 hours during which the overflow was weighed. In the last test, that of engine No. 3, using superheated steam, water was found to leak into the steam space of the condenser to such an extent that a subsequent test of five hours was made under similar conditions, and the weight of the overflow then obtained was taken to represent the steam consumption of the pumping engine.

At the close of each test all bearings were found to be reasonably cool. The boilers were also taken out of service and found to be in good condition.

The head used in computing the duty of the pumping engines was the mean reading of the mercury column on the discharge main, less the mean elevation of the water in the shaft, no allowance being made for friction through the pumps or connections.

The amount of water delivered by the pumps per revolution was calculated from weir measurements taken for a period of about 6 hours at the beginning of each test. The weir in question was fifteen feet in length, with an average head of about 0.98 feet, the Fteley & Stearns formula, $Q = 3.31\ L.\ H^{\frac{3}{2}} + 0.007\ L.$ being used in the computations.

The several tests were conducted under the direction of Mr. G. H. Benzenberg, Chief Engineer of the Board of Trustees, "Commissioners of Water Works," by Mr. S. G. Pollard, Mechanical Engineer, representing the "Commissioners," and Mr. John H. Lewis, representing the Camden Iron Works, each being aided by an efficient corps of assistants.

The following is a record and principal and additional results of each test, together with the averages of all observations:

OFFICIAL DUTY AND CAPACITY TRIAL.

Pumping Engine No. 3 and Battery No. 3, using saturated steam. Date, 11.00 A. M., September 1, 1908, to 11.00 A. M., September 7, 1908, and of pumping engine No. 4 and battery No. 4, using saturated steam. Date, 12 M., September 16, 1908, to 12 M., September 22, 1908. Duration each, 144 hours.

GENERAL DATA AND RESULTS.

CORRECTED PRESSURES.	No. 3	No. 4.
	Pounds.	Pounds.
Steam pressure indicated by boiler gauge	153.46	151.25
Steam pressure indicated by engine gauge	151.43	148.892
Steam pressure indicated by 1st receiver gauge	27.05	27.81
Steam pressure indicated by 2nd receiver gauge	—1.89	—2.15
Vacuum gauge	—13.81	—13.92
Steam pressure in H. P. jacket	151.43	149.785
Steam pressure in I. P. jacket	30.46	35.7
Steam pressure in L. P. jacket	—2.175	— 0.501
	Feet.	Feet.
Pressure indicated by gauge on force main	147.494	147.498
Pressure indicated by gauge on suction main	7.767	5.678
Mean head in feet during test	139.27	141.820
TEMPERATURES.		
Outside air	72° F.	73° F.
Boiler room air	84°	90°
Gases leaving boiler	322°	360°
Water as pumped	74.1°	73.37°
Feed water entering auxiliary heater	92.6°	92.6°
Feed water leaving auxiliary heater	142.8°	137°
Feed water entering economizer	142.8°	137°
Feed water leaving economizer	199.5°	212°
DRAUGHT GAUGES.		
Air pressure in stokers, in inches of water	1.08	1.72
Draughts over fires	—0.151	—0.032
Draughts at rear upper door	—0.111	—0.046
Draught in flue	—0.462	—0.068
Draught in stack	—0.62	—0.036
FEED WATER in pounds.		
Condensed steam from cylinders	1,071,502	1,127,620
Total jacket steam in pounds	179,279	187,389
Total steam used by engine	1,250,781	1,315,009
Steam used by stokers, (approximate)	16,808	17,088
Steam used by fan engine (approximate)	50,446	57,600
Steam used by economizer engine (approximate)		1,124
Total steam accounted for (approximate)	1,318,035	1,390,821
Leakage (estimated) 1%	13,180	13,908
Total feed water to boilers (approximate)	1,331,215	1,404,729
Total dry steam from boilers	1,304,591	1,376,634
Total dry steam used by engine	1,238,273	1,301,859

FUEL, in pounds.	No. 3.	No. 4.
Total weighed coal	140,386	142,722
Taken out for samples, etc	318	325
Total wet coal consumed	140,068	142,397
Moisture in coal	2.2%	1.77%
Total dry coal	136,986	139,877
Total ash and refuse	10,731	12,524
Percentage of ash in coal	7.83%	8.79%
Amount of slate picked from coal	1,521	1,795
Percentage of slate to total coal	1.085%	1.26%
Total combustible	124,734	125,558

MISCELLANEOUS DATA.

Speed of fan engine	195 R.P.M.	224 R. P. M.
No. hours economizer engine was run	45	43.25
Steam used by stokers per 100 lb wet coal	12	13
Steam used by fan engine per hour	350	400
Percent of moisture in steam at engine	1%	1%
Percent of moisture in steam at boilers	2%	2%
Average length of stroke of engine	96″	96″
Gallons displaced per revolution	1,377	1,377
Gallons pumped per revolution (weir measure)	1,370.712	1,367.403
Weight of one gallon of water	8.325625	8.32647
Total revolutions of engine, 144 hours	134,287	133,911
Revolutions per hour	932.55	929.94
Revolutions per minute	15.54	15.50

WEIR DATA.

Length of weir	15′0″	15′0″
Width of channel	25′0″	25′0″
Length of approach	77′6″	77′6″
Average depth below crest	5.3′	5.3′
Average head on crest	0.97424′	0.9679′
Gallons by weir measurement per revolution of engine	1,370.712	1,367.403

PRINCIPAL RESULTS.

Total water measured by weir in gals	183,821,983	182,863,545
Total leakage in force main	246,758	246,758
Total pumpage by weir measurement, gallons	184,068,741	183,110,303
Total pumpage by displacement in gallons	184,913,199	184,395,447
Percent of slippage of pumps	0.4566	0.69695
Gallons pumped in 24 hours, weir measure	30,878,124	30,518,384
Guaranteed capacity per 24 hours	30,000,000	30,000,000
Excess capacity over guarantee, weir measure	678,124	518,384
Per cent excess capacity over guarantee, weir measure	2.260	1.728
Gallons pumped per hour, weir measure	1,278,255	1,271,599
Duty per 100 lb. coal as weighed, weir measure	152,875,648	151,848,398
Duty guaranteed per 100 lb. coal as weighed	115,000,000	115,000,000
Excess duty over guarantee	37,875,648	36,848,398
Duty per 100 lb. dry coal, weir measure	156,315,138	154,584,119
Duty per 1000 lb. dry steam, weir measure	172,925,997	166,091,628

ADDITIONAL RESULTS, BOILER PLANT.

Water actually evaporated per pound of dry coal from actual pressure and temperature	9.524	9.842
Factor of evaporation for boiler plant	1.1221	1.1279
Equivalent water evaporated by boiler plant per pound of dry coal from and at 212° F.	10.687	11.101
Water actually evaporated per pound of combustible from actual pressure and temperature	10.459	10.964
Equivalent water evaporated by boiler plant per pound of combustible from and at 212° F	11.736	12.366
Factor of evaporation for boilers only	1.0630	1.0495
Equivalent water evaporated by boilers only per pound of dry coal from and at 212° F.	10.124	10.329
Percentage of total work done by boilers only	94.73	93.05
Percentage of total work done by economizer	5.27	6.95

ADDITIONAL RESULTS, BOILER PLANT—Continued	No. 3.	No. 4.
Total boiler horse-power developed by plant	294.7	312.6
Total boiler horse-power developed by boilers only	279.0	290.9
Water evaporated from and at 212° F. per square foot of heating surface per hour, boilers only	2.389	2.488
Water necessary to be evaporated per square foot of boiler heating surface per hour under test conditions, if economizer was out of service	2.522	2.674
Dry coal actually burned per square foot of grate surface per hour	11.325	11.564
B. T. U. per pound of dry coal	13,244	13,333
Efficiency of boiler plant	77.92%	80.4
Dry steam delivered to engine per pound of dry coal	9.039	9.307

SMOKE OBSERVATIONS	No. 3		No. 4.	
	Hours	Per cent	Hours	Per cent
Total hours observed	62.5		60.5	
Smoke less than 1 minute per hour	19	30.4	22.0	36.36
Smoke more than 1 minute per hour	43.5	69.6	38.5	63.63
Smoke more than 2 minutes per bour	33.0	52.8	34.5	57.02
Smoke more than 3 minutes per hour	20	32.0	32.5	53.71
Smoke more than 4 minutes per hour	18	28.8	21.0	34.71
Smoke more than 5 minutes per hour	15	24.0	12.5	20.66
Smoke more than 6 minutes per bour	12	19.2	8.0	13.22
Smoke more than 7 minutes per hour	9	14.4	7.0	11.57
Smoke more than 8 minutes per hour	8	12.8	7.0	11.57
Smoke more than 9 minutes per hour	4	6.4	5.0	8.26
Smoke more than 10 minutes per hour	3	4.8	4.0	6.61
Smoke more than 11 minutes per bour	3	4.8	4.0	6.61
Smoke more than 12 minutes per hour	2	3.2	4.0	6.61
Smoke more than 13 minutes per bour	1	1.6	4.0	6.61
Smoke more than 14 minutes per hour	------	------	4.0	6.61
Smoke more than 15 minutes per hour	------	------	2.0	3.30
Smoke more than 16 minutes per hour	------	------	2.0	3.30
Smoke more than 17 minutes per hour	------	------	1.0	1.65
Smoke more than 18 minutes per hour	------	------	1.0	1.65

Official Duty and Capacity Trial.

Pumping engine No. 1, battery No. 3, using superheated steam. Date, 11.00 A. M., October 5, 1908, to 11.00 A. M., October 11, 1908, and of pumping engine No. 3 and battery No. 4, using superheated steam. Date, 10.00 A. M., October 27, 1908, to 10.00 A. M., November 2, 1908. Duration, each 144 hours.

General Data and Results.

CORRECTED PRESSURES.	No. 1.	No. 3.
	Pounds.	Pounds.
Steam pressure indicated by boiler gauge	152.95	153.16
Steam pressure indicated by engine gauge	149.77	149.93
Steam pressure indicated by 1st receiver gauge	26.396	24.61
Steam pressure indicated by 2nd receiver gauge	—3.25	— 2.75
Vacuum gauge	—13.99	—14.1
Steam pressure in H. P. jacket	149.7	149.93
Steam pressure in I. P. jacket	29.82	28.0
Steam pressure in L. P. jacket	—3.205	—2.498
	Feet	Feet
Pressure indicated by gauge on force main	147.699	147.653
Elevation of water in shaft	4.458	7.646
Mean head in feet during test	143.241	140.007

TEMPERATURES.

Outside air	61°F	47.8°F
Boiler room air	87°	89.1°
Gases leaving boiler	437°	361.1°
Water as pumped	60.8°	55.46°
Feed water entering auxiliary heater	83°	81.0°
Feed water leaving auxiliary heater	127°	121.7°
Feed water entering economizer	127°	121.7°
Feed water leaving economizer	212°	202.2°
Steam entering superheater	364°	364.9°
Steam leaving superheater	520°	491°
Steam at engine	461.8°	461.4°
Gases leaving superheater	373°	368.7°

DRAUGHT GAUGES.

Air pressure in stokers, in inches of water	1 3	1.48
Draught over fire of superheater	—.118	—.051
Draught at rear upper door	—.044	—.019
Draught in stack	—.643	—.662
Draught in flue	—.387	—.469

FEED WATER, in pounds.

Condensed steam from cylinders	1,026,288	994,332
Total jacket steam	129,442	116,219
Total steam used by engine	1,155,730	1,110,551
Steam used by stokers and fan engine	57,404	54,719
Total steam accounted for (approximate)	1,213,134	1,165,270
Leakage (estimated) ½% at boilers, ½% beyond superheater—total 1%	12,131	11,653
Total feed water to boilers	1,225,265	1,176,923
Total dry steam from boilers	1,206,886	1,159,260
Total dry steam from superheaters	1,219,200	1,171,096

FUEL, in pounds.	No. 1.	No. 3.
Total weighed coal for boilers	122,204	121,252
Coal taken out for samples	278	264
Total coal consumed under boilers	121,926	120,988
Total weighed coal for superheaters	10,845	10,474
Coal taken out for samples	31	34
Total coal consumed under superheater	10,814	10,440
Total coal consumed	132,740	131,428
Moisture in coal	2.099%	1.7413%
Total dry coal consumed by boilers	119,367	118,881
Total dry coal consumed by superheater	10,587	10,259
Total dry coal consumed	129,954	129,140
Total ash from boiler coal	11,043	11,284
Percentage of ash	9.06	9.33
Total ash from superheater coal	1,006	398
Percentage	9.30	
Total ash	12,049	11,682
Percentage	9.08	8.9
Amount of slate picked from coal	808	738
Percentage of slate	0.61	0.561
Total noncombusible in boiler coal	11,785	11,963
Total noncombustible in superheater coal	1,072	457
Total noncumbustible	12,857	12,420
Total combustible in boiler coal	107,582	106,918
Total combustible in superheater coal	9,515	9,802
Total combustible	117,097	116,720

MISCELLANEOUS DATA.

Speed of fan engine	194 R.P.M.	202.3 R.P.M.
Number hours economizer engine was run	7	21
Percent of moisture in steam of boilers	1½%	1½%
Average length of stroke of engine	96 inches	96 inches
Gallons displaced per revolution	1,377	1,377
Gallons pumped per revolution—weir measure	1,376.876	1,370.712
Weight of one gallon of water	8.337656	8.34033
Total revolutions of engine	133,320	134,269
Revolutions per hour	925.8	932.4
Revolutions per minute	15.43	15.54

WEIR DATA.

Length of weir	15′0″	15′0″
Width of channel	25′0″	25′0″
Length of approach	77′6″	77′6″
Average depth below crest	5′3″	5′3″
Average head on crest	0.97564′	0.97424′
Gallons by weir measure, per revolution of engine	1,376.876	1,370.712

PRINCIPAL RESULTS.

Total water measured by weir in gallons	183,318,385	183,797,372
Total leakage in force main in gallons	246,758	246,758
Total pumpage by weir measure in gallons	183,565,143	184,044,130
Total pumpage by displacement in gallons	183,581,640	184,888,413
Slippage of pumps, percent	0.009	0.4566
Gallons pumped per 24 hours, weir measure	30,594,191	30,674,022
Guaranteed capacity per 24 hours, gallons	30,000,000	30,000,000
Excess over guarantee	594,191	674,022
Percent of excess	1.981	2.247
Gallons pumped per hour, weir measure	1,274,758	1,278,084
Duty per 100 lb. coal as weighed, weir measure	165,158,101	163,518,560
Duty guaranteed per 100 lb. coal used	115,000,000	115,000,000
Excess duty over guarantee	50,158,101	48,518,560
Duty per 100lb. coal as weighed, plunger displacement	165,194,803	164,268,685
Duty ger 100 lb. coal, weir measurement	168,698,770	166,415,652
Duty per 1000 lb. dry steam, plunger displacement	189,707,388	194,403,500
Duty per 1000 lb. dry steam, weir measure	189,690,305	193,515,854

ADDITIONAL RESULTS—BOILER PLANT—Excluding Superheater.

Water actually evaporated per pound of dry coal from actual pressure and temperature	10.111	9.741
Factor of evaporation for boiler plant	1.1377	1.144
Equivalent water evaporated by boiler plant per pound of dry coal from and at 212° F.	11.504	11.155
Water actually evaporated per pound of combustible from actual pressure and temperature	11 218	10 842
Equivalent water evaporated by boiler plant per pound of combustible from and at 212° F.	12.762	12.403
Factor of evaporation for boilers only	1.0490	1.060
Equivalent water evaporated by boilers only per pound of dry coal from and at 212° F	10.607	10.336
Percentage of total work done by boilers only	92.20	92.66
Percentage of total work done by economizer	7.80	7.34
Total boiler H. P. developed by plant	276.4	266.95
Total boiler H. P. developed by boilers only	254.9	247.34
Water evaporated from and at 212° F. per square foot of heating surface per hour boilers only	2.18	2.117
Water necessary to be evaporated per square foot of boiler heating surface per hour under test conditions, if economizer was out of service	2.365	2.285
Dry coal actually burned per square foot of grate surface per hour	9.868	9.83
B. T. U. per pound of dry coal	13,280	13,254
Efficiency of boiler plant, percent	83.6	81.3
Dry steam delivered to engine per pound of dry coal	8.893	8.60

ADDITIONAL RESULTS, Superheater.

Steam superheated per pound of dry coal	115.2	114.2
Contained water evaporated per pound of dry coal	1.73	1.71
Specific heat of superheated steam taken as	0.58	0.58
Heat absorbed in superheating steam per pound dry coal, B. T. U.	8217	8350
Heat absorbed in evaporating contained water per pound dry coal, B. T. U.	1476	1459
Total heat delivered to steam per pound dry coal, B. T. U.	9693	9809
Total heat per pound of coal B. T. U.	13,280	13,254
Efficiency of superheater per cent	73.00	74.00
Degrees superheat at boilers	123.0	126.1
Degrees superheat at engine	96.3	95.8

SMOKE OBSERVATIONS.

	No. 1		No. 3.	
	Hours.	Percent.	Hours.	Percent.
Total hours observed	66		69	
Smoke less than 1 minute per hour	3	4.5	7.5	10.9
Smoke more than 1 minute per hour	63	95.5	61 5	89.1
Smoke more than 2 minutes per hour	59	89.4	46.0	66.7
Smoke more than 3 minutes per hour	53	89.4	32.0	46.4
Smoke more than 4 minutes per hour	58	87.9	24.5	35.5
Smoke more than 5 minutes per hour	52	78.8	16.5	23.9
Smoke more than 6 minutes per hour	48	72.7	11.0	16.0
Smoke more than 7 minutes per hour	45	68.2	9.	13.1
Smoke more than 8 minutes per hour	43	65.1	8	11.6
Smoke more than 9 minutes per hour	37	56.1	7	10.2
Smoke more than 10 minutes per hour	26	39.4	5	7.3
Smoke more than 11 minutes per hour	22	33.3	3	4.4
Smoke more than 12 minutes per hour	19	28.8	2	2.9
Smoke more than 13 minutes per hour	15	22.7	2	2.9
Smoke more than 14 minutes per hour	13	19.7	2	2.9
Smoke more than 15 minutes per hour	11	16.7	2	2.9
Smoke more than 16 minutes per hour	9	13.6	1	1.45
Smoke more than 17 minutes per hour	6	9.1	1	1.45
Smoke more than 18 minutes per hour	4	6.1	1	1 45
Smoke more than 19 minutes per hour	4	6.1	1	1.45
Smoke more than 20 minutes per hour	3	4 5	1	1.45
Smoke more than 21 minutes per hour	3	4.5	1	1.45
Smoke more than 22 minutes per hour	3	4.5	1	1.45
Smoke more than 23 minutes per hour	1	1.5	1	1.45
Smoke more than 24 minutes per hour	1	1.5	1	1.45
Smoke more than 25 minuter per hour	1	1.5	1	1.45
Smoke more than 26 minutes per hour	1	1.5	0	0.00
Smoke more than 27 minutes per hour	1	1.5		
Smoke more than 28 minutes per hour	1	1.5		
Smoke more than 29 minutes per hour	1	1.5		
Smoke more than 30 minutes per hour	1	1.515		

APPENDIX G

REPORT OF OFFICIAL DUTY AND CAPACITY TRIALS OF THE PUMPING ENGINES AT THE MAIN STATION, NEW WATER WORKS, CINCINNATI, OHIO.

The pumping equipment of this station consists of three twelve million gallons and three twenty-five million gallons vertical, triple-expansion pumping engines, built by the Holly Manufacturing Co., of Buffalo, N. Y., known respectively as the high service and low service pumps, together with twelve Geary water-tube boilers, set in batteries of two each, built by the Oil City Boiler Works, also Green Economizers, heaters, feed pumps, and other auxiliaries.

Each engine is equipped with an exhaust heater, surface condenser, an attached air pump, air compressor, and boiler feed pump. An independent air compressor, New York Air Brake Company's make, is also provided for each service. The exhaust steam from the low-pressure cylinder flows through the exhaust heater to the condenser, thence to the air pump, which removes the condensed water and vapor, and maintains a vacuum in the condenser.

The water pumped is taken from a suction header 60 inches in diameter for the high service and 72 inches in diameter for the low service, which are connected with the tunnel shaft by an 84-inch diameter pipe. The water enters the pump chambers under a static head and is pumped into the discharge mains, 48 and 60 inches in diameter respectively. Cold water for the condensers is shunted from the suction pipe at each engine by means of a butterfly valve. After passing through the condensers it is returned to the suction pipes.

Each high-service pumping engine, with its appurtenances, is guaranteed to be capable of delivering 12 million U. S. gallons of water in twenty-four hours, against a total head of 412 to 506 feet when running at a piston speed of not more than 200 feet per minute, and to be capable of developing a test duty of 135 million foot pounds of work for every 100 pounds of dry Pittsburg nut and slack coal consumed by the boilers during a continuous run of 120 hours when pumping at the rate of not less than 12 million U. S. gallons per 24 hours against a total head of approximately 415 to 460 feet.

Each low-service pumping engine, with its appurtenances, is guaranteed to be capable of delivering 25 million U. S. gallons of water in 24 hours against a total head of 154 to 225 feet when running at a piston speed of not more than 200 feet per minute, and to be capable of developing a test duty of 135 million foot pounds of work for every 100 pounds of dry Pittsburg nut and slack coal consumed by the boilers during a continuous run of 120 hours when pumping at a rate of not less than 25 million U. S. gallons per 24 hours against a total head of approximately 154 to 182 ft.

Under the foregoing guarantees 160 pounds per square inch steam pressure is required at the engines.

The principal dimensions of the pumping engines and appurtenances are given below:

	H. S.	L. S.
Capacity in 24 hours, gallons	12,000,000	25,000,000
Number of steam cylinders	3	3
Diameter of H. P. cylinder	34″	32″
Diameter of I. P. cylinder	64″	60″
Diameter of L. P. cylinder	98″	90″
Diameter of all piston rods	8″	7½″
Piston speed, feet per minute	200	200
Number of revolutions per minute	20	20
Normal stroke of pistons	60″	60″
Type of steam valve gear	Corliss & Poppet	Corliss & Poppet
Number of re-heaters	2	2
Surface of tubing in 1st re-heater, sq. ft	165	157
Surface of tubing in 2nd re-heater, sq. ft	300	285
Length of main shaft	12′ 7½″	12′ 1½″
Diameter main shaft at middle	23⅜″	22″
Diameter of main shaft journals	20″	19″
Length of main shaft journals	32″	32″
Diameter—crank pin journal	12½″	12″
Length—crank pin journal	11″	11″
Diameter—cross head pin journal	12½″	12″
Length—cross head pin journal	11″	11″
Number of fly wheels	2	2
Diameter of fly wheel	20′	20′
Weight of each flywheel, tons	38	35
Number of pumps	3	3
Diameter of main pump plungers	26½″	38½″
Normal stroke of plunger	60″	60″
Diameter of pump barrel	38″	55″
Diameter of pump valve chamber	59″	61″
Number of discharge pump valves	480	540
Number of suction pump valves	480	540
Effective area of valves for one pump	824 sq. in.	1440 sq. in.
Diameter of valves	3⅝″	4 3/16″
Proportion of valve area to plunger area	149 %	126 %
Diameter of discharge—two to each engine	22″	30″
Kind of condenser	Surface.	Surface.
Size of condenser	5′ 11″ x 13′ 6″	5′ 11″ x 12′ 6″
Condensing surface—square feet	2200	2000
Number of attached air pumps	1	1
Diameter—attached air pump cylinder	24″	24″
Stroke attached air pump piston	60″	60″
Number of attached feed pumps	1	1
Diam. of attached feed pump cylinder	3½″	3½″
Stroke of attached feed pump plunger	60″	60″
Number of attached air compressors	1 two-stage	1 single-stage
Diameter of attached air compressor cylinder	2½″-3″	3″
Stroke of attached air compressor piston	60″	60″
Heating surface of exhaust heater—sq. ft.	314	314

Steam for these pumping engines is supplied by six batteries, each consisting of two Geary water tube boilers, equipped with American underfeed stokers. The boiler plant correspondingly consists of three high-service and three low-service batteries. The boilers of each service are equipped with large Green economizers for No. 1 and No. 2 batteries, and a smaller one for No. 3 battery of boilers. The dimensions are given below. Two brick stacks, 8 feet by 150 feet, are provided, one for the high service and one for the low service batteries. Forced draught is supplied by two 10-inch by 10-inch Buffalo Forge Company's engines, each driving a 92-inch direct connected Buffalo Forge Co. fan. Two auxiliary boiler-feed pumps of Snow Steam Pump Company's make are provided, also one Erie City Iron Works feed water heater.

The exhaust steam from the fan engines, stokers, economizer engines, and auxiliary feed pumps is used here to raise the temperature of the feed water just before entering the economizers. The course of the feed water in reaching the boiler is from the suction main to exhaust heater in the engine, to hot well, where condensed jacket steam is added, through attached feed pumps to auxiliary heater to economizer and into boiler.

The principal dimensions of the boilers and auxiliaries are given below:

	H. S.	L. S.
Number of batteries	3	3
Number of boilers in each battery	2	2
Number of tubes in each boiler	140	116
Diameter of boiler tubes	3½"	3½"
Length of boiler tubes	15'0"	16'0"
Diameter of drum	42"	42"
Length of drum	19'6"	20'6"
Total water heating surface per boiler	2069 sq. ft.	1855 sq. ft.
Total superheating surface each boiler	22 sq. ft.	22.5 sq. ft.
Total H. P., builder's rating, each	207	185.5
Length of grate, front wall to bridge wall	6'2"	6'2"
Width of grate, wall to wall	7'0"	6'7"
Grate area	43.16 sq. ft.	40.60 sq. ft.
Ratio heating surface to grate surface	47.94 to 1	45.69 to 1
Green economizers, No. sections for battery 3	24	20
Green economizers, heating surface battery 3	2,104.4 sq. ft.	1,753.7 sq. ft.
Green economizers, No. sections batteries 1 and 2	44	40
Green economizers, heating surface batteries 1 and 2	3858.1 sq. ft.	3507.4 sq. ft.
Auxiliary heater, heating surface	327 sq. ft.	327 sq. ft.

The tests made consisted of duty trials of two high-service engines and two low-service engines, with their corresponding batteries of boilers and auxiliaries, the time and duration of each test being as follows:

H. S. No. 3	12:30 P. M., July 28, 1908 to 12:30 P. M., Aug. 2, 1908.
L. S. No. 3	12:00 M. Sept. 9, 1908 to 12:00 M. Sept. 14, 1908.
H. S. No. 2	3:00 P. M., Sept. 28, 1908 to 3:00 P. M., Oct. 3, 1908.
L. S. No. 2	11:00 A. M., Oct. 19, 1908 to 11:00 A. M., Oct. 24, 1908.

The test of H. S. No. 3 engine was actually started at 8.30 A. M., July 28, 1908, and stopped at 4.30 P. M., August 2, 1908, continuing for 128 hours, but it was mutually agreed between the representatives of the contractors and the "Commissioners of Water Works" to reject the first four and last four hours of the test run, thus cutting the test time down to 120 hours as specified in the contract.

Previous to starting the various duty trials, all steam and exhaust pipes connecting the machinery under test with other parts of the plant were either disconnected or blanked off. All gauges were carefully calibrated before starting, and important gauges were again calibrated at the end of each test. All scales were tested by the City Sealer of Weights and Measures.

The boilers used were carefully examined and cleaned, both inside and out, and all scale was removed from the tubes by turbining. The economizers were also cleaned and turbined, and all soot accumulations were removed from the smoke flues and stacks. All parts of the boiler under test were put in good working condition, and all air leaks about the boiler settings were carefully stopped.

Before starting any of the duty trials the representatives of the contractor claimed that they were entitled to allowances for a part of the steam furnished the fan engine and for the slate in the coal. These allowances were refused, and have not been considered in calculating the duty of the pumping engines. The contractor's representatives picked the slate from the coal after it had been weighed to the boilers and a record of the weight and percentage of the slate is incorporated in this report. The contractors also made several tests of the amount of steam used by the fan engines in which tests the "Commissioners" representatives took no part. The results of these tests, however, have been used in this report in making up the statement of boiler performances.

Each engine, with its corresponding battery of boilers and other appurtenances, was operated under its contract conditons for several hours previous to starting the official duty trial. At the time of starting, the condition of the fires and the height of the water in the gauge glasses of the boilers were observed, and the fires and water levels were brought to the same condition at the close of the test.

The coal used was the ordinary Pittsburg nut and slack coal, as furnished in the Cincinnati market. No allowances of any kind were made except for the moisture in the coal. This was determined by taking a weighed sample (about 5 pounds) from each car (about 2,000 pounds of coal) and placing it over the boilers for 24 hours, after which it was weighed again. The average percentage of loss from these determinations was taken as the percentage of moisture in the coal. All coal delivered to the boilers under test and all ashes removed from the furnaces were carefully weighed. Hourly readings were taken of the steam pressure at the boilers and also of the temperatures, draught, gauges, etc. Observations of the steam pressure at the engine, first and second receiver pressures, jacket steam pressures, vacuum gauge, revolution counter, and the suction and discharge water pressures were taken every 15 minutes throughout the test. Observations were also taken of the color and duration of the smoke issuing from the stacks during the daylight hours of the tests. No smoke was considered which was not of a darker color than that allowed by the city ordinance.

The overflow from the attached air pump was also weighed during each test. As the contractors were entitled to the heat in the jacket trap discharges, the jacket steam was not weighed, but additional tests of several hours were made on each engine while running under similar conditions to determine this quantity. The amount of steam used by the fan engine, economizer engine, and stokers was estimated from tests previously made.

At the conclusion of each test the engines were examined, and all bearings were found to be reasonably cool. The boilers were also taken out of service and found to be in good condition, except in the case of boiler "A," battery No. 2, low service, which had two tubes slightly bagged.

The head used in computing the duty of each pumping engine was the mean difference between the readings of the gauges on the suction and discharge headers inside the engine room, corrected for the difference in elevation of these gauges, no allowance being made for friction through the pumps or connections.

The amount of water delivered by the pumps was calculated from the plunger displacement, all valves having been made tight and leakages having been reduced to a minimum.

The several tests were conducted under the direction of Mr. G. H. Benzenberg, Chief Engineer of the Board of Trustees, "Commissioners of Water Works;" by Mr. S. G. Pollard, Mechanical Engineer, representing the "Commissioners," and Mr. Chas. H. Anderson, representing the Holly Manufacturing Company, each being aided by an efficient corps of assistants.

The following is a record of the principal and additional results of each test of the pumping machinery at the Main Pumping Station, together with the averages of all observations:

Official Duty and Capacity Tests.

H. S. Engine No. 3 and Battery No. 3, H. S. Boilers. Date, 12.30 P. M., July 28, 1908, to 12.30 P. M., August 2, 1908, and of H. S. Engine No. 2 and Battery No. 2, H. S. Boilers. Date, 3.00 P. M., September 28, 1908, to 3.00 P. M., October 3, 1908. Duration each, 120 hours.

General Data and Results.

CORRECTED PRESSURES.	No. 3	No. 2.
	Pounds.	Pounds.
Steam pressure indicated by boiler gauge	161.05	157.73
Steam pressure indicated by engine gauge	156.19	154.00
Steam pressure indicated by first receiver gauge	29.59	29.08
Steam pressure indicated by 2nd receiver gauge	—2.99	—3.69
Vacuum gauge, inches of mercury	25.71	26.407
Steam pressure in H. P. jacket	156.19	154.00
Steam pressure in I. P. jacket	35.64	35.27
Steam pressure in L. P. jacket	2.99	2.61
Pressure indicated by gauge on force main	193.54	193.545
	Feet	Feet
Pressure indicated by gauge on force main	448.054	447.282
Pressure indicated by gauge on suction main	33.319	33.646
Elevation of gauge on force main	80.00	80.50
Elevation of gauge on suction main	57.17	57.17
Vertical distance between centers of two gauges	22.83	23.33
Mean head in feet during test	437.565	436.966

CORRECTED TEMPERATURES.

Outside air	86.7°F	52.0°F
Boiler room air	94.0°	74.0°
Gases leaving boiler, electric pyrometer	523.0°	477.0°
Gases leaving boiler, mercury thermometer	523.0°	477.0°
Stack temperature	235.0°	195.0°
Water as pumped	82.7°	70.7°
Feed water entering engine heater	93.1°	80.0°
Feed water leaving engine heater	124.5°	120.0°
Feed water entering auxiliary heater	122.7°	123.0°
Feed water leaving auxiliary heater	201.5°	179.0°
Feed water entering economizer	197.8°	176.0°
Feed water leaving economizer	259.1°	233.0°

DRAUGHT GAUGES.

Air pressure in stokers, in inches of water	2.065	2.36
Draughts over fires	—0.117	—0.053
Draughts at rear upper door	—0.160	—0.109
Draught in stack	—0.415	—0.471

FEED WATER, in pounds.

Condensed steam from cylinders	1,166,032	1,171,108
Total jacket steam in pounds	166,743	167,301
Total steam used by engines	1,332,775	1,338,409
Steam used by stokers (approximately)	18,181	18,052
Steam used by fan engine (approximately)	118,200	104,760
Steam used by economizer engine (approximately)	658	825
Approximate total steam accounted for	1,469,814	1,462,046
Leakage, (estimated) 1 per cent	14,698	14,620
Total feed water to boilers (approximately)	1,484,512	1,476,666
Total dry steam from boilers	1,454,822	1,447,133
Total dry steam used by engine	1,303,454	1,308,964

FUEL, in pounds.	No. 3.	No. 2.
Total weighed coal	151,852	150,750
Taken out for samples, etc	344	313
Total wet coal consumed	151,508	150,437
Moisture in coal	2⅓ %	2.3816 %
Total dry coal	147,973	146,854
Total ash	14,319	13,070
Percentage of ash in coal	9.45 %	8.69 %
Amount of slate picked from coal	845	839
Percentage of slate to total coal	0.557 %	0.55 %
Total incombustible	15,164	13,909
Total combustible	132,809	132,945

MISCELLANEOUS DATA

Speed of fan engine	264.79 R.P.M.	263 R. P. M.
Number of hours economizer engine was run	13⅛ hours	16.5 hours
Steam used by stokers per 100 lb. wet coal (approximately)	12.00 lb.	12.00 lb.
Steam used by fan engine per hour (approximately)	985 lb.	873 lb.
Steam used by economizer engine per hour (approximately)	50 lb.	50 lb.
Percent of moisture in steam at engine	2.20 %	2.20 %
Percent of moisture in steam at boilers	2 %	2 %
Average length of stroke at engine	59.875″	59.88802″
Gallons pumped per revolution	428.880628	428.973890
Head of water at 82.7° F. equivalent to 1 lb. pressure	2.3150′	2.3110′
Weight of 1 gallon of water at 82.7° F.	8.3153319	8.3296357
Total revolutions of engines, 120 hours	144,973	144,741
Revolutions per hour	1,208.11	1,206.175
Revolutions per minute	20.135	20.103

PRINCIPAL RESULTS.

Gallons pumped in 120 hours	62,176,111	62,090,110
Gallons pumped per day of 24 hours	12,435,222	12,418,022
Excess over contract requirements	3.627 %	3.483 %
Gallons pumped per hour	518,134	517,417.6
Total foot pounds during test	226,227,669,350	225,993,570,242
Duty per 100 lbs. of dry coal	152,884,425	153,889,966
Duty per 100 lbs. of coal as weighed	149,317,310	150,224,725
Duty per 1000 lbs. of dry steam	173,560,148	172,650,715

ADDITIONAL RESULTS—BOILER PLANT.

Water actually evaporated per lb. of dry coal from actual pressure and temperature	9.832lb	9.854lb
Factor of evaporation for boiler plant	1.065	1.0874
Equivalent water evaporated by boiler plant per lb. of dry coal from and at 212 °F	10.471lb	10.715lb
Water actually evaporated per lb. of combustible from actual pressure and temperature	10.954lb	10.885lb
Equivalent water evaporated by boiler plant per lb. of combustible from and at 212° F.	11.666lb	11.837lb
Factor of evaporation for boilers only	1.002	1.027
Equivalent water evaporated by boilers only per lb. dry coal from and at 212° F	9.852lb	10.126lb
Percentage of total work done by boilers only	94.1 %	94.5 %
Percentage of total work done by economizer	5.9 %	5.5 %
Total boiler H. P. developed by plant	374.4	380.10
Total boiler H. P. developed by boilers only	352.3	359.20
Water evaporated from and at 212° F. per square foot of heating surface per hour boilers only	2.935	2.995
Water necessary to be evaporated per square foot of boiler heating surface per hour under test conditions if economizer was out of service	3.120lb	3.169lb
Dry coal actually burned per square foot of grate surface per hour	14.284lb	14.177
B. T. U. per pound of dry coal	13,679	13,100
Efficiency of boiler plant	73.92 %	78.90 %
Dry steam delivered to engine per lb. of dry coal	8.809lb	8.913lb

SMOKE OBSERVATIONS.

	No. 3.		No. 2.	
	Hours.	Per cent.	Hours.	Per cent.
Total hours observed	82		50	
Smoke less than 1 minute per hour	1	1.22	19	38
Smoke more than 1 minute per hour	81	98.78	31	62
Smoke more than 2 minutes per hour	78	95.27	21	42
Smoke more than 3 minutes per hour	72	87.80	16	32
Smoke more than 4 minutes per hour	67	81.70	15	30
Smoke more than 5 minutes per hour	55	67.07	11	22
Smoke more than 6 minutes per hour	43	52.44	7	14
Smoke more than 7 minutes per hour	39	47.57	4	8
Smoke more than 8 minutes per hour	27	32.92	2	4
Smoke more than 9 minutes per hour	18	21.95	2	4
Smoke more than 10 minutes per hour	12	14.63	0	0
Smoke more than 11 minutes per hour	11	13.42		
Smoke more than 12 minutes per hour	6	7.32		
Smoke more than 13 minutes per hour	3	3.66		
Smoke more than 14 minutes per hour	3	3.66		
Smoke more than 15 minutes per hour	3	3.66		
Smoke more than 16 minutes per hour	2	2.44		
Smoke more than 17 minutes per hour	0	0.00		

Boilers under east stack were used during duty trial.

SUMMARY.

High Service Engine No.	3	2	1
Average water pumped in 24 hours, U. S. Gallons	12,435,222	12,418,022	----------
Guaranteed capacity	12,000,000	12,000,000	----------
Excess over guarantee, per cent	3.627	3.484	----------
Duty per 100 lbs. dry coal	152,884,425	153,889,966	153,387,196
Duty guaranteed	135,000,000	135,000,000	135,000,000
Excess duty above guarantee	17,884,425	18,889,966	18,387,196

Average duty Engines, Nos. 2 and 3, 153,387,196.

Note: Mean duty Engines, Nos. 2 and 3 taken as duty of Engine No. 1.

OFFICIAL DUTY AND CAPACITY TRIALS.

L. S. Engine No. 3 and Battery No. 3, L. S. Boilers. Date, 12.00 M., September 9, 1908, to 12.00 M., September 14, 1908, and of L. S. Engine No. 2 and Battery No. 2, L. S. Boilers. Date, 11.00 A. M., October 19, 1908, to 11 A. M., October 24, 1908. Duration each, 120 hours.

GENERAL DATA AND RESULTS.

CORRECTED PRESSURES.	No. 3.	No. 2.
	Pounds.	Pounds.
Steam pressure indicated by boiler gauge	160.16	159.80
Steam pressure indicated by engine gauge	153.96	154.44
Steam pressure indicated by 1st receiver gauge	24.05	25.67
Steam pressure indicated by 2nd receiver gauge	—3.74	—3.85
Vacum gauge inches of mercury	26.76	26.83
Steam pressure in H. P. jacket	153.96	154.44
Steam pressure in I. P. jacket	28.48	29.76
Steam pressure in L. P. jacket	2.98	2.40
Pressure indicated by gauge on force main	73.69	74.078
	Feet	Feet
Pressure indicated by gauge on force main	170.401	171.081
Pressure indicated by gauge on suction main	26.523	26.348
Elevation of gauge on force main	80.00	80.50
Elevation of gauge on suction main	57.17	57.17
Vertical distance between centers of two gauges	22.83	23.33
Mean head in feet during test	166.708	168.063

CORRECTED TEMPERATURES.

Outside air	76.0°F.	76.0°F.
Boiler room air	91.8°	74.7°
Gases leaving boiler, electric pyrometer	394.0°	402.0°
Gases leaving boiler, mercury thermometer	394.0°	402.0°
Stack temperature—pyrometer		196.0°
Water as pumped	75.7	63.8
Feed water entering engine heater	88.6	66.7
Feed water leaving engine heater	114.8	112.8
Feed water entering auxiliary heater	113.8	117.5
Feed water leaving auxiliary heater	195.7	183.0
Feed water entering economizer	189.5	178.4
Feed water leaving economzier	214.2	223.6

DRAUGHT GAUGES.

Air pressure in stokers, in inches of water	2.03	1.76
Draughts over fires	—0.016	—.035
Draughts at rear upper door	—0.021	—.065
Draught in stack	—0.389	—.294

FEED WATER, in pounds.

Condensed steam from cylinders	975,110	991,174
Leakage	12,000	15,600
Actual condensed steam from cylinders	963,110	975,574
Total jacket steam in pounds	133,826	135,558
Total steam used by engine	1,096,136	1,111,132
Steam used by stokers (approximately)	15,384	15,733
Steam used by fan engine (approximately)	92,400	68,400
Steam used by economizer engine (approximately)	711	813
Approximate total steam accounted for	1,205,431	1,196,078
Leakage (estimated) 1 per cent	12,054	11,961
Total feed water to boilers (approximately)	1,217,485	1,208,039
Total dry steam from boilers	1,193,135	1,183,878
Total dry steam used by engine	1,072,803	1,086,688

FUEL, in pounds.	No. 3.	No. 2.
Total weighed coal	128,457	131,419
Taken out for samples, etc	256	309
Total wet coal consumed	128,201	131,110
Moisture in coal	1.7672 %	2.2641 %
Total dry coal	125,935	128,142
Total ash	11,740	12,099
Percentage of ash in coal	9.32 %	9.23 %
Amount of slate picked from coal	995	914
Percent of slate—total coal	7.76 %	0.698 %
Total incombustible	12,735	13,013
Total combustible	113,200	118,097

MISCELLANEOUS DATA.

Speed of fan engine	251 R. P. M.	228 R. P. M.
Number of hours economizer engine was run	14 hrs. 13 min.	16.25
Steam used by stokers per 100 lb. wet coal (approximately)	12.00	12.00lb
Steam used by fan engine per hour (approximately)	770lb	570lb
Steam used by economizer (approximately) per hour	50lb	50lb
Percent of moisture in steam at engine	2.2 %	2.20 %
Percent of moisture in steam at boilers	2.0 %	2.00 %
Average length of stroke of engine	59.88802"	59.88021"
Gallons pumped per revolution	893.721056	893.604476
Weight of one gallon of water	8.3246895	8.3352503
Total revolutions of engines—120 hours	144,500	145,418
Revolutions per hour	1,204.166	1,211.817
Average revolutions per minute	20.694	20.197

PRINCIPAL RESULTS

Gallons pumped in 120 hours	129,142,693	129,946,176
Gallons pumped per day of 24 hours	25,828,539	25,989,235
Gallons pumped per hour	1,076,189	1,082,885
Excess over contract requirements	3.314 %	3.957 %
Total foot pounds developed	179,223,239,746	182,034,733,054
Duty per 100 lb. dry coal	142,314,082	142,057,041
Duty per 100lb. coal as weighed	139,798,629	138,841,227
Duty per 1000 lb. dry steam	167,060,718	167,513,337

ADDITIONAL RESULTS, BOILER PLANT

Water actually evaporated per lb. of dry coal from actual pressure and temperature	9.474lb	9.239lb
Factor of evaporation for boiler plant	1.0736	1.0851
Equivalent water evaporated by boiler plant per lb. of dry coal from and at 212°F.	10.171lb	10.025lb
Water actually evaporated per lb of combustible from actual pressure and temperature	10.540lb	10.025lb
Equivalent water evaporated by boiler plant per lb. of combustible from and at 212°F.	11.316lb	10.878lb
Factor of evaporation for boilers only	1.0477lb	1.0378
Equivalent water evaporated by boilers only per lb. of dry coal from and at 212°F.	9.926lb	9.588lb
Percentage of total work done by boilers only	97.59 %	95.64 %
Percentage of total work done by economizer	2.41 %	4.36 %
Total boiler H. P. developed by plant	309.4	310.30
Total boiler H. P. developed by boilers only	301.9	296.8
Water evaporated from and at 212°F. per square foot of heating surface per hour boilers only	2.818	2.770
Water necessary to be evaporated per square foot of boiler heating surface per hour under test conditions if economizers were out of service	2.888	2.896
Dry coal actually burned per square foot of grate surface per hour	12.92	13.151
B. T. U. per pound of dry coal	13,260	13,473
Efficiency of boiler plant	74.07 %	71.86 %
Dry steam delivered to engine per pound of dry coal	8.518	8.480

SMOKE OBSERVATIONS

	No. 3		No. 2	
	Hours	Percent.	Hours.	Percent.
Total hours observed	60		53	
Smoke less than 1 minute per hour	1.0	1.67	3	5.7
Smoke more than 1 minute per hour	59.0	98.33	50	94.3
Smoke more than 2 minutes per hour	57.0	95.0	46	86.8
Smoke more than 3 minutes per hour	50.0	83.33	27	51.0
Smoke more than 4 minutes per hour	39.5	65.83	24	45.4
Smoke more than 5 minutes per hour	31.5	52.50	14	26.4
Smoke more than 6 minutes per hour	27.5	45.83	11	20.8
Smoke more than 7 minutes per hour	19.5	32.50	6	11.3
Smoke more than 8 minutes per hour	16.0	26.67	6	11.3
Smoke more than 9 minutes per hour	13.0	21.67	2	3.8
Smoke more than 10 minutes per hour	12.0	20.00	2	3.8
Smoke more than 11 minutes per hour	9.0	15.00	2	3.8
Smoke more than 12 minutes per hour	8.0	13.33	1	1.9
Smoke more than 13 minutes per hour	6.0	10.00	1	1.9
Smoke more than 14 minutes per hour	6.0	10.00		
Smoke more than 15 minutes per hour	5.0	8.33		
Smoke more than 16 minutes per hour	4.0	6.67		
Smoke more than 17 minutes per hour	3.0	5.0		
Smoke more than 18 minutes per hour	2.0	3.33		
Smoke more than 19 minutes per hour	2.0	3.33		
Smoke more than 20 minutes per hour	2.0	3.33		
Smoke more than 21 minutes per hour	1.0	1.67		

SUMMARY

Low Service Engine.	No. 3	No. 2	No. 1.
Average water pumped in 24 hours U. S. Gallons	25,828,539	25,989,235	----------
Guaranteed capacity	25,000,000	25,000,000	----------
Excess over guarantee, percent	3.314	3.957	----------
Duty per 100 pounds dry coal	142,314.082	142,057,041	142,185,562
Duty guaranteed	135,000,000	135,000,000	135,000,000
Excess duty above guarantee	17,314,082	17,057,041	17,185,562

Average duty Engines Nos. 2 and 3. 142,185,562.

Note—Mean duty Engines Nos. 2 and 3 taken as duty of Engine No. 1.

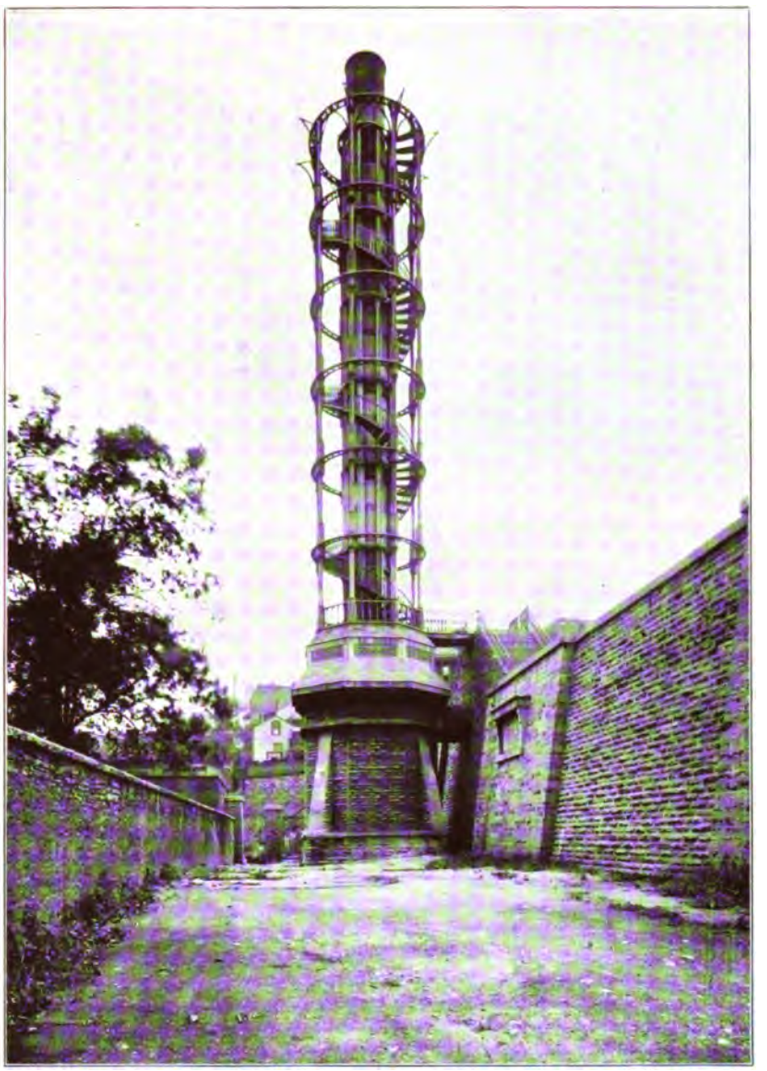

PLATE A — Old Stand Pipe adjoining Third Street Reservoirs.

PLATE B — View of Third Street Reservoirs.

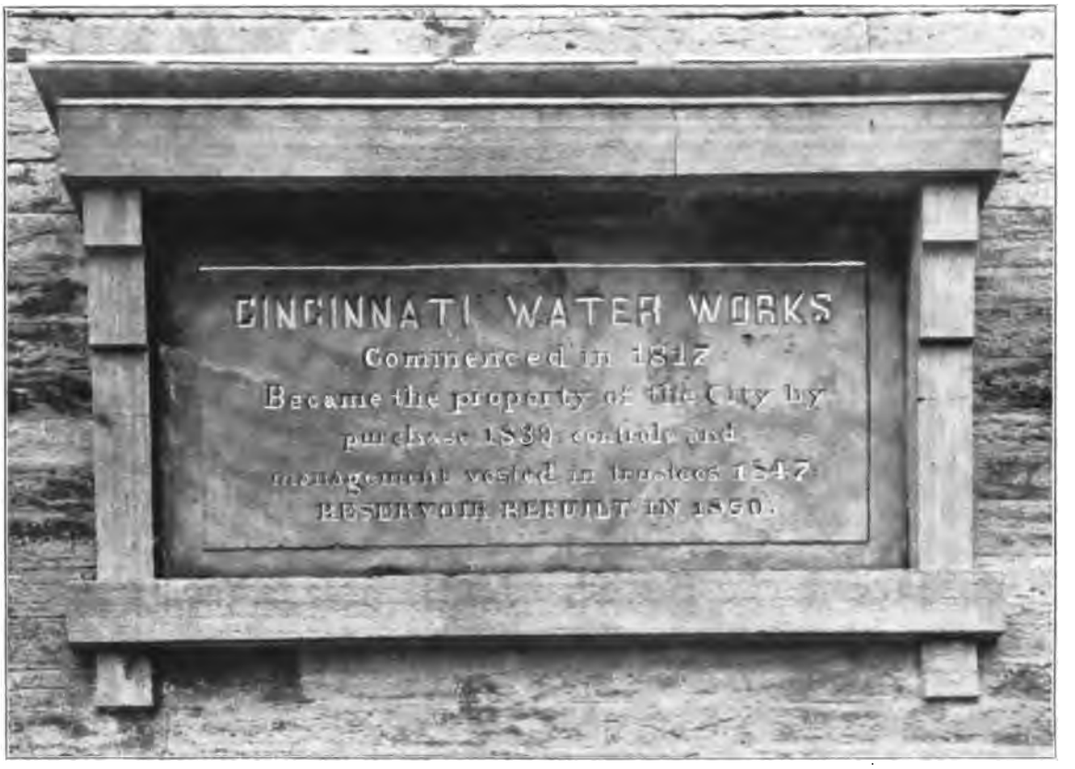
CINCINNATI WATER WORKS
Commenced in 1817
Became the property of the City by
purchase 1839 control and
management vested in trustees 1847
RESERVOIR REBUILT IN 1860.

PLATE C — Stone Tablet in Wall of old Third Street Reservoir.

PLATE 1 — Original Bank of Little Miami River.

PLATE 2 — Miami River Bank Revetment Under Construction.

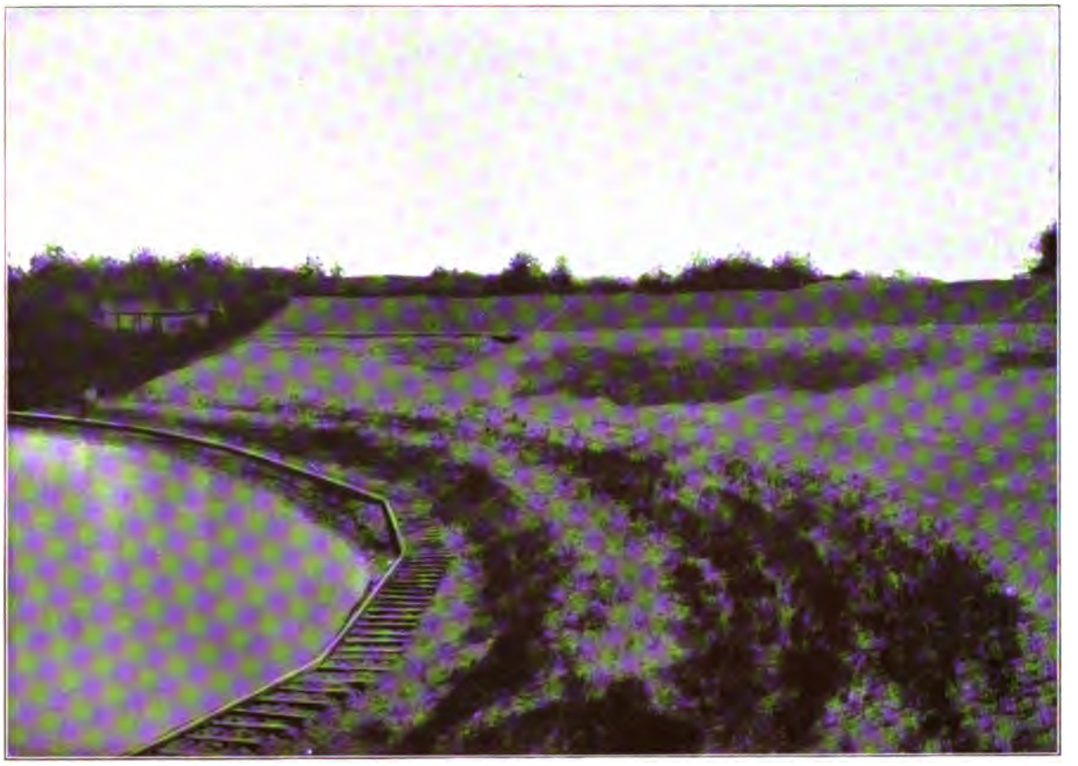

PLATE 3 — Miami River Bank Revetment Completed.

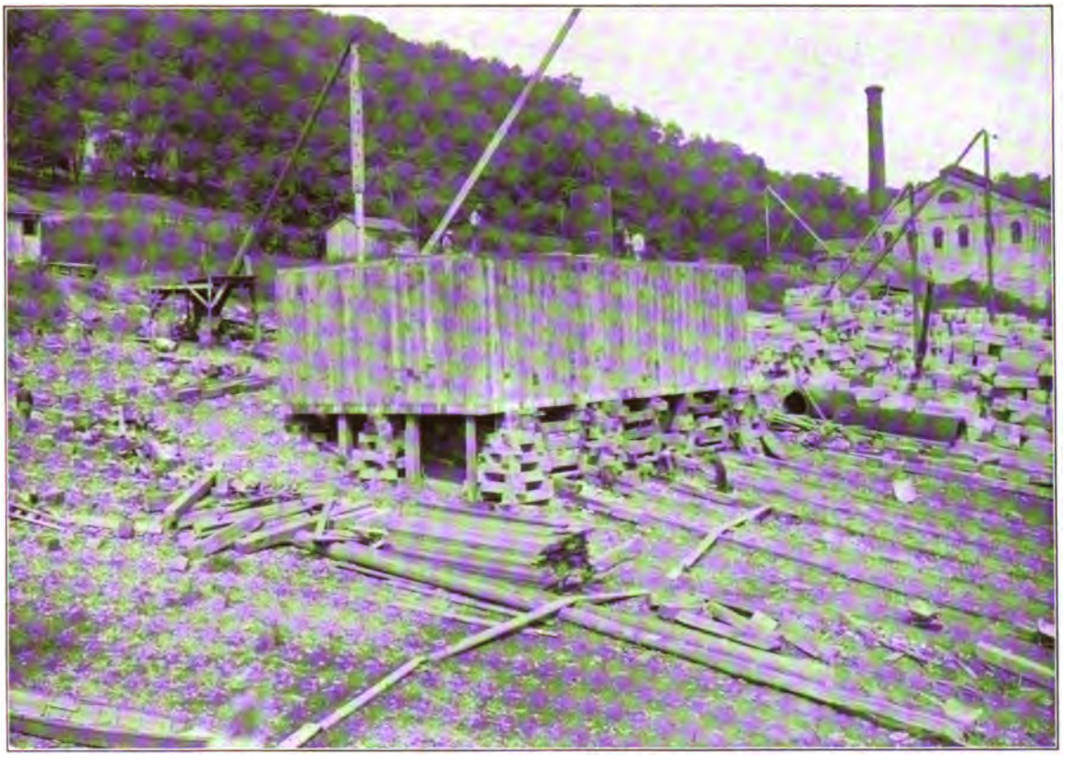

PLATE 4 — Intake Pier Caisson on Shore, Under Construction.

PLATE 5 — Intake Pier Caisson in Place.

PLATE 6 — Intake Pier Nearly Completed.

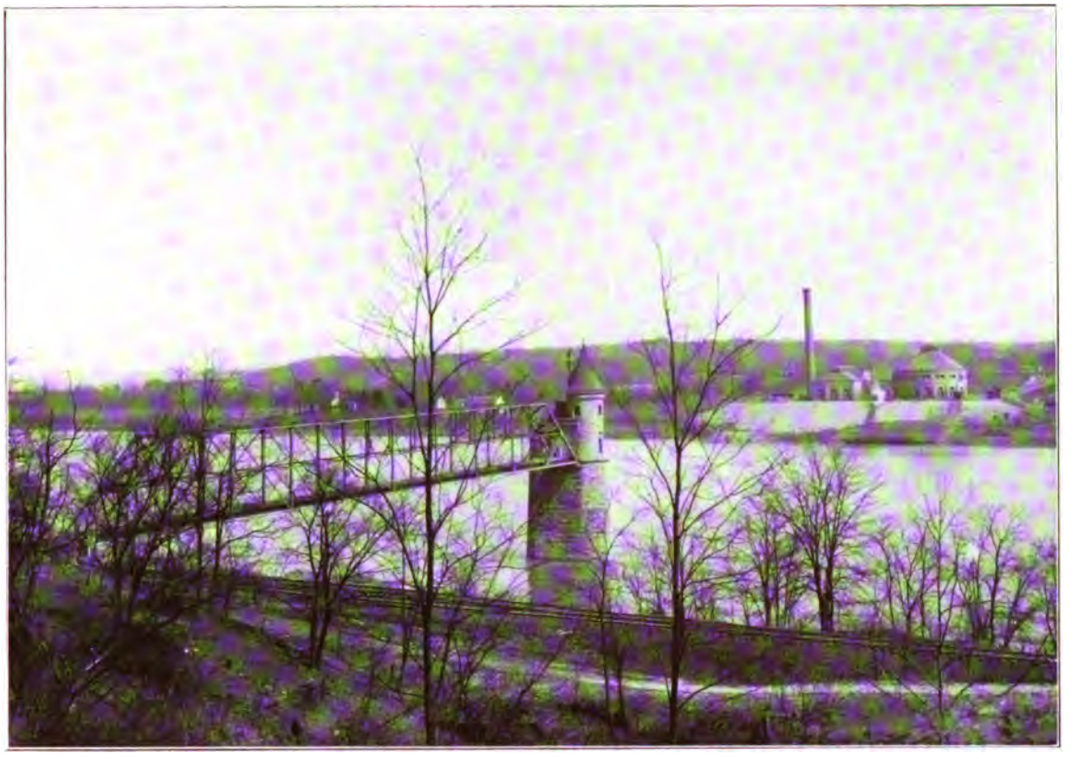

PLATE 7 — View of Intake Pier and Bridge from Kentucky Shore.

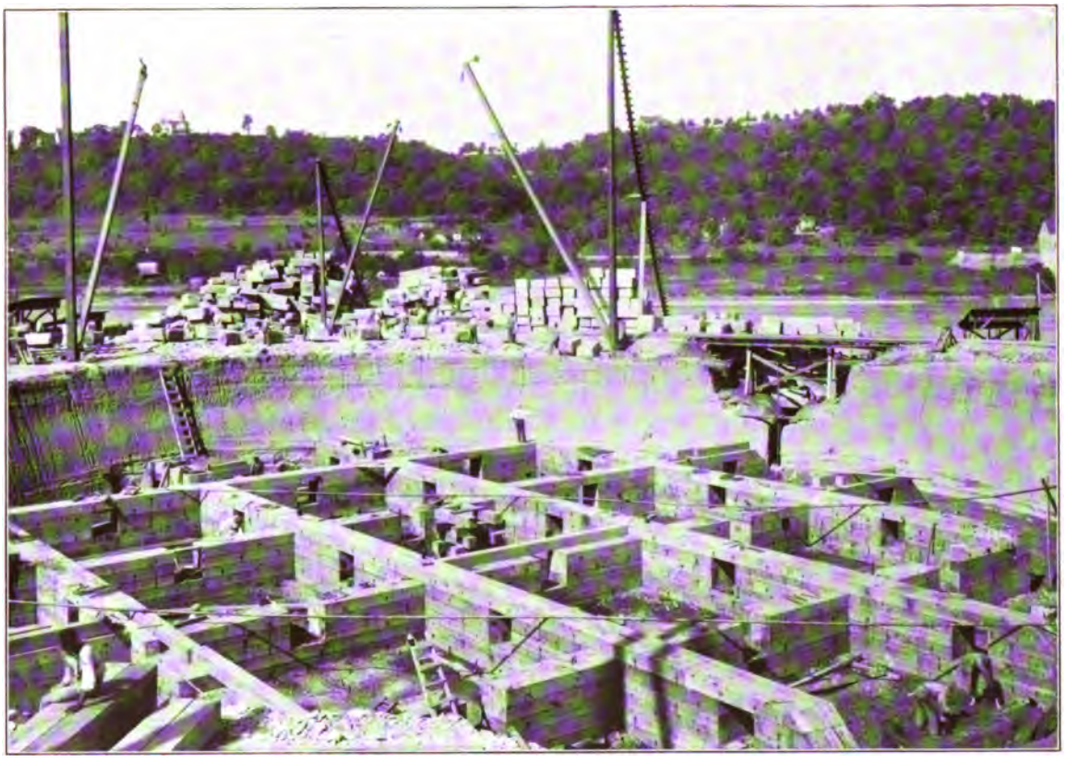

PLATE 8 — Pump Pit Caisson, Showing Cross Walls Under Deck.

PLATE 9 — Pump Pit Caisson, Showing Cutting Edge and First Tier of Deck

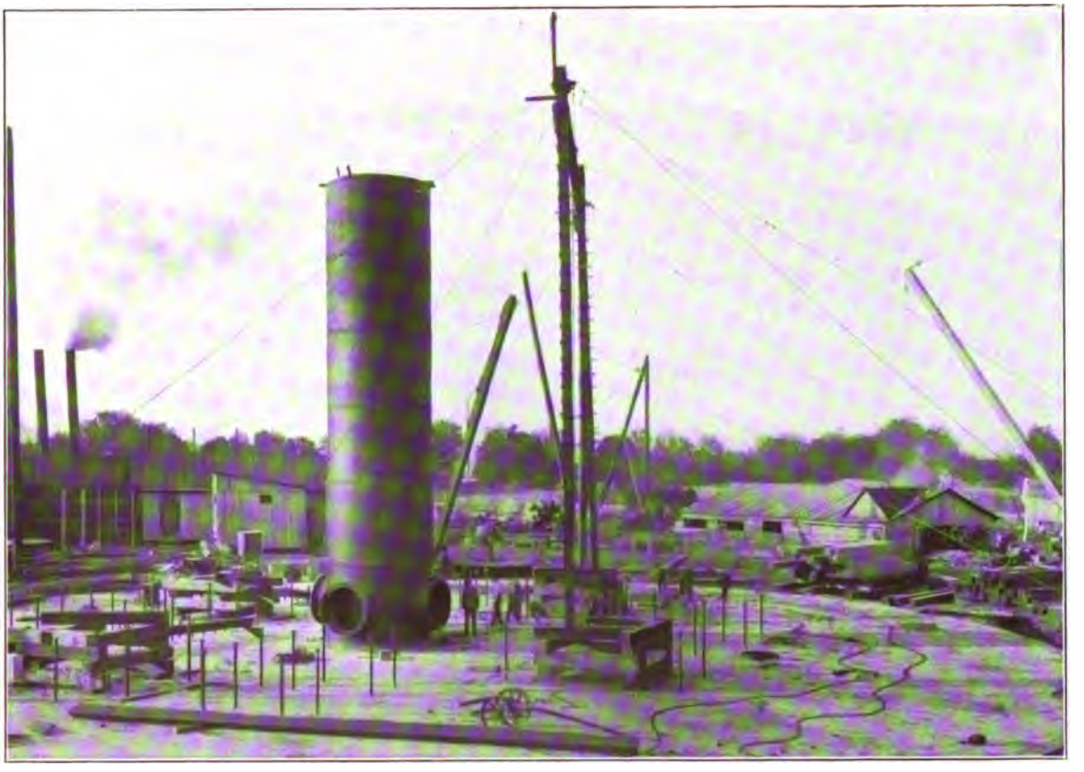

PLATE 10 — Pump Pit Caisson, Showing Top of Deck and Intake Shaft.

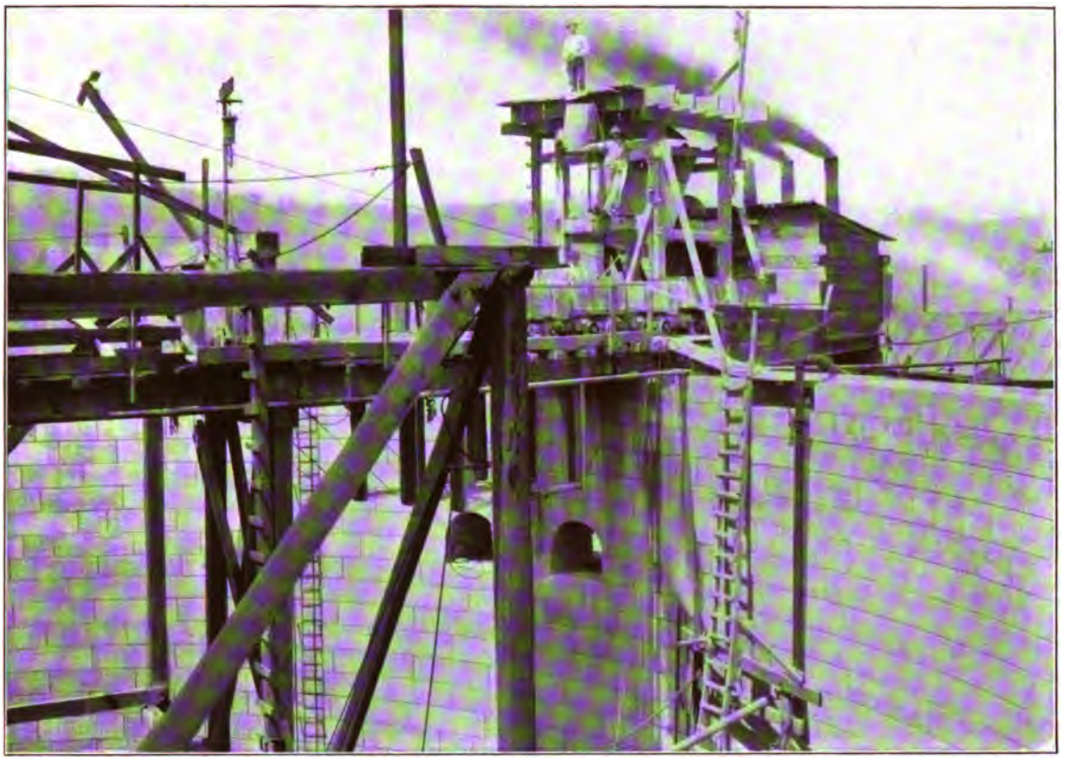

PLATE 11 — Pump Pit Nearly Completed, Showing Masonry Walls.

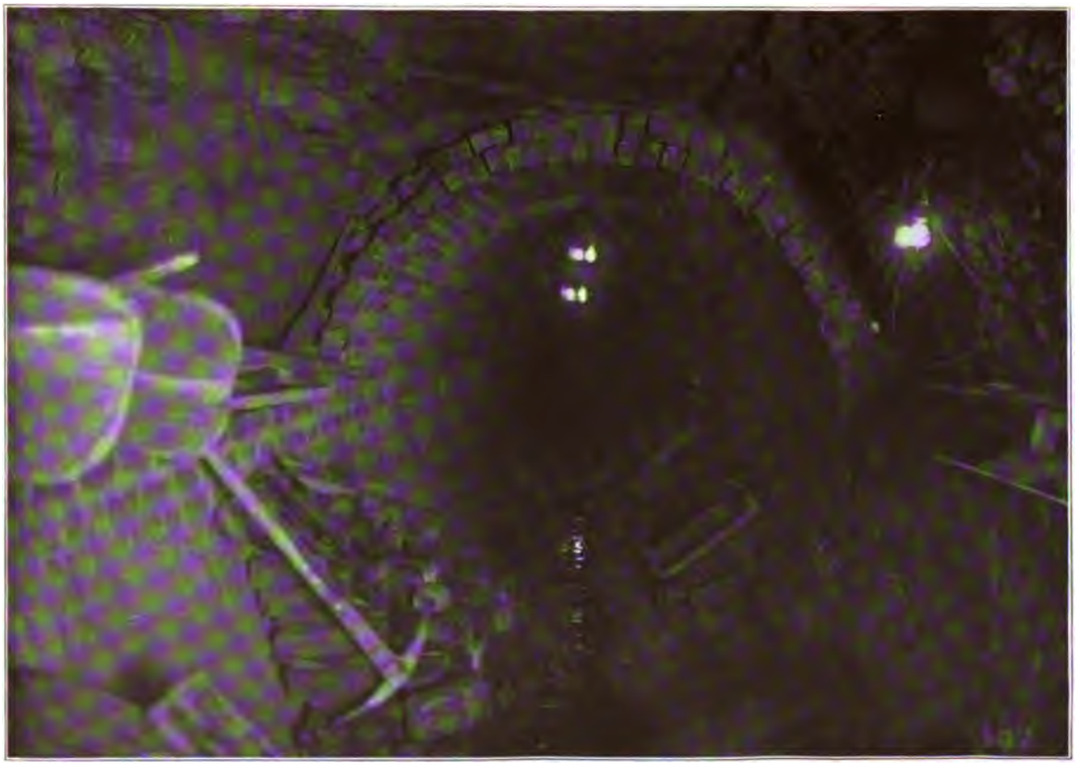

PLATE 12 — River Tunnel, Under Construction.

PLATE 13 — Embankment Around Pump Pit.

PLATE 14 — Grading Levee Embankment.

PLATE 15 — Unloading Sixty-inch Cast-iron Pipe.

PLATE 16 — Laying Double Line of Sixty-inch Pump Mains on Levee.

PLATE 17 — Buildings at River Pumping Station Under Construction.

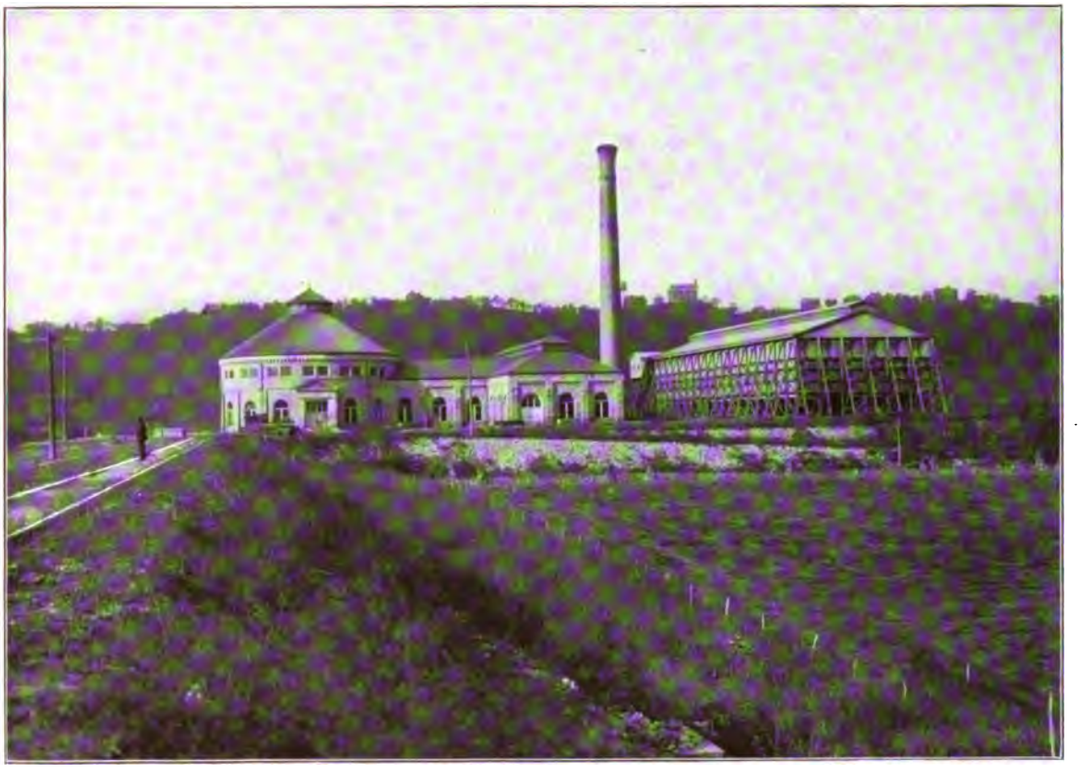

PLATE 18 — River Pumping Station, Completed.

PLATE 19 — River Station During High Water, January 23, 1907.

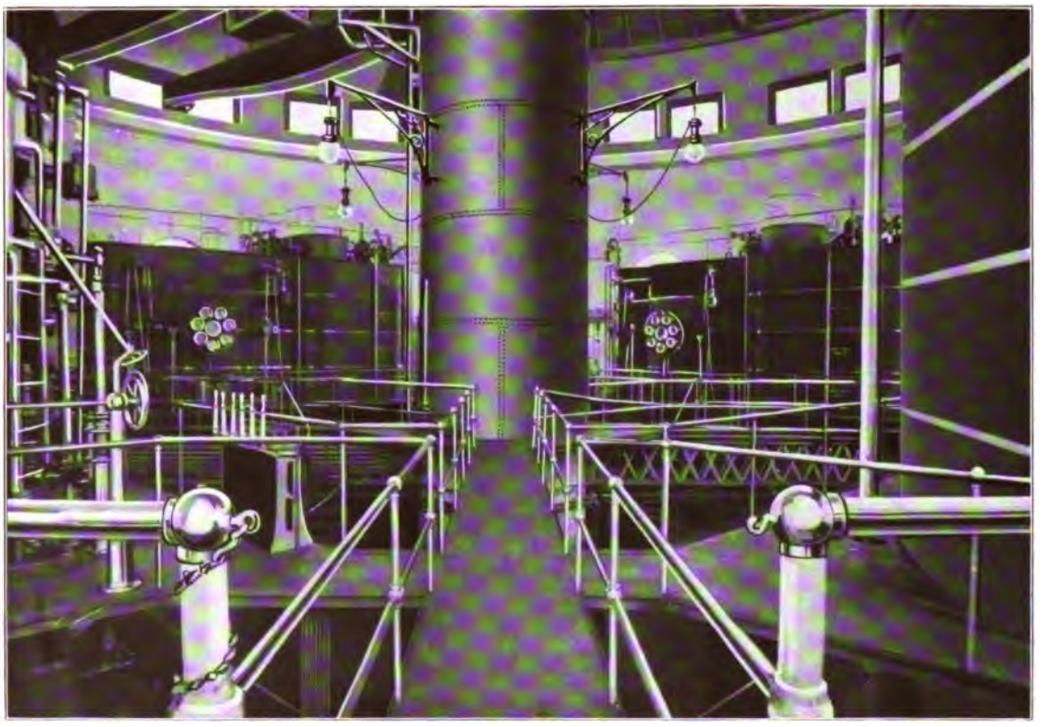

PLATE 20 — Interior of Engine Room at River Station.

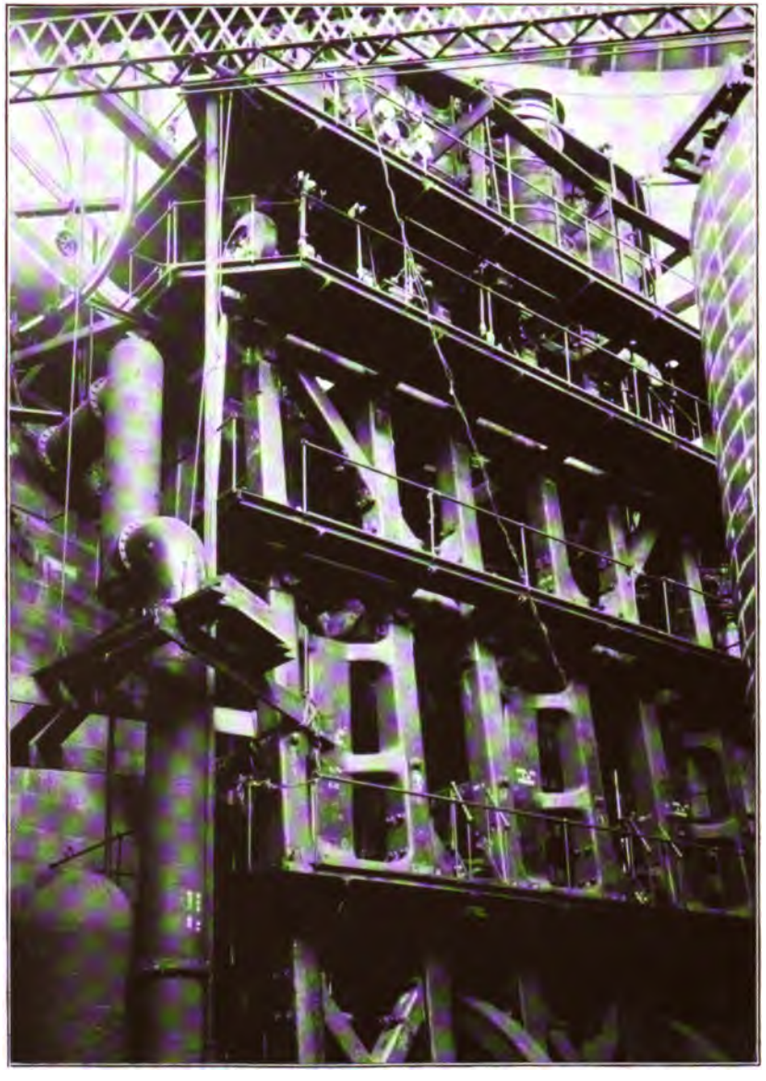

PLATE 21 — Upper Half of Pumping Engine at River Station.

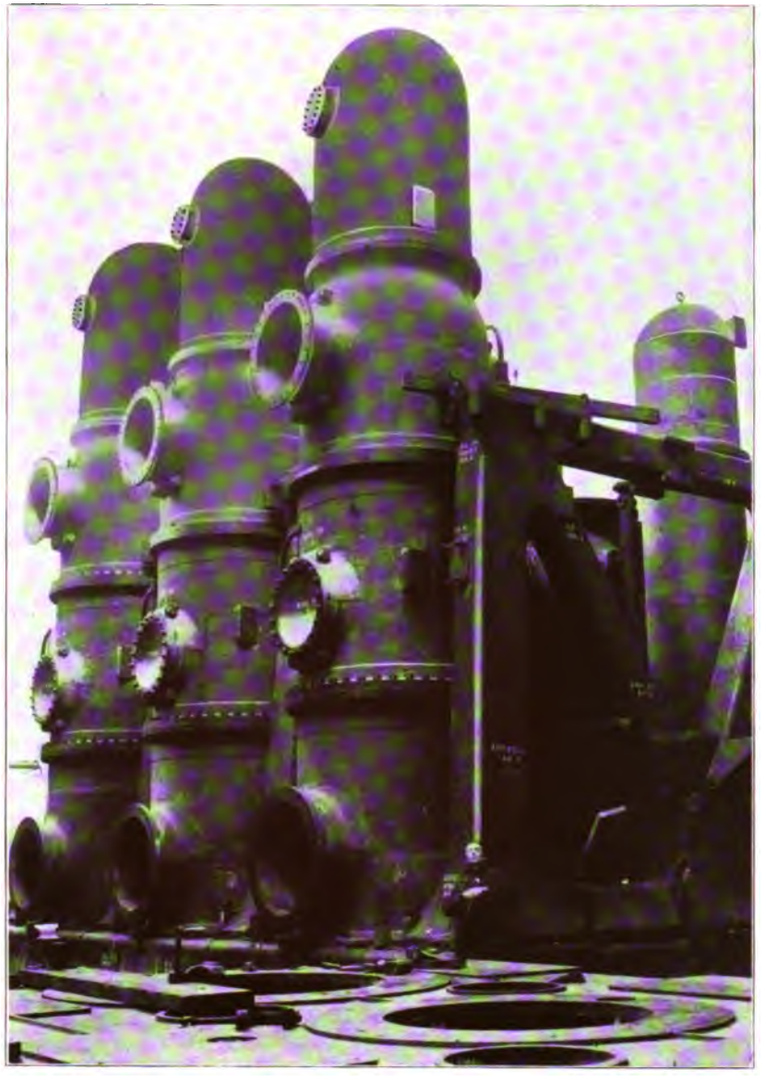

PLATE 22 — Pump Air Chambers at River Pumping Station.

PLATE 23 — Site of Settling Reservoir No. 1.

PLATE 24 — Site of Settling Reservoir No. 2.

PLATE 25 — Site of Dam, Reservoir No. 1.

PLATE 26 — Excavation for Archway Under Dam, Reservoir No. 1.

PLATE 27 — Stage of Excavation for Archway Under Dam, Reservoir No. 2, August, 1901.

PLATE 28 — Stage of Work on Dam of Reservoir No. 1, when Work was Suspended, August, 1901.

PLATE 29 — Growth on Unfinished Work, Thirty Days After Work was Suspended.

PLATE 30 — Character of Conglomerate in Excavation of Reservoir No. 1.

PLATE 31 — Basin of Reservoir No. 2, Completed.

PLATE 32 — Laying Double Line of Sixty-inch Mains Along Dam of Reservoir No. 1.

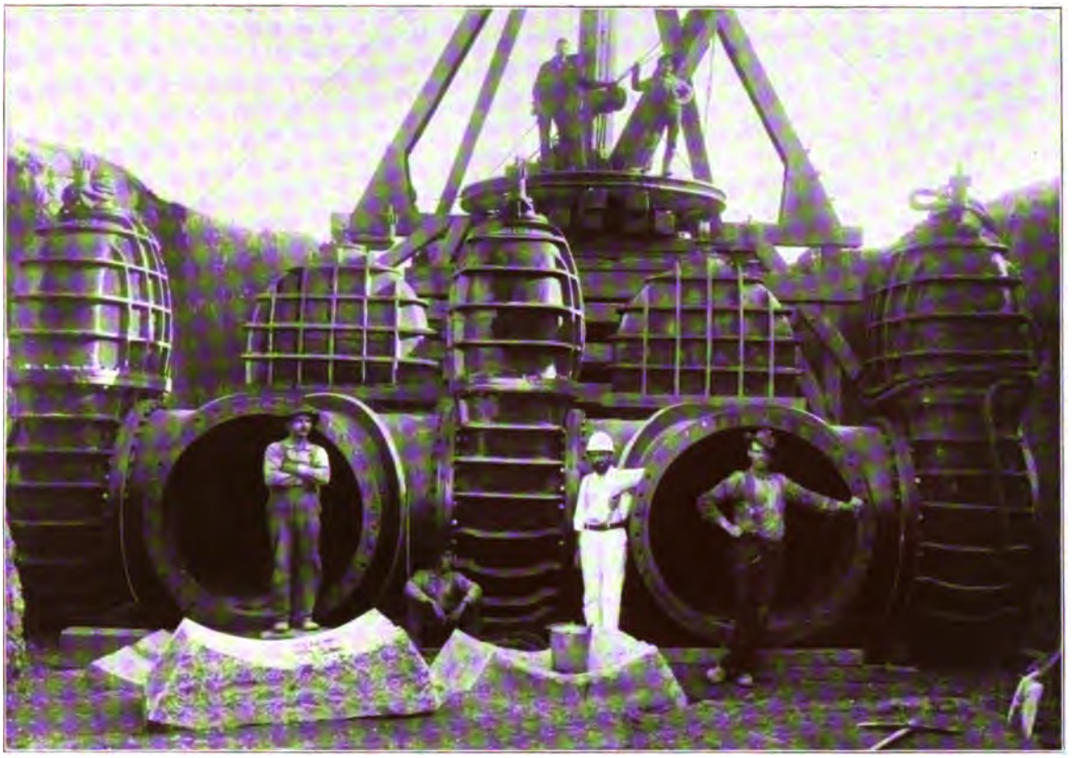

PLATE 33 — Setting Sixty-inch Gate Valves at Weir Between Reservoirs 1 and 2.

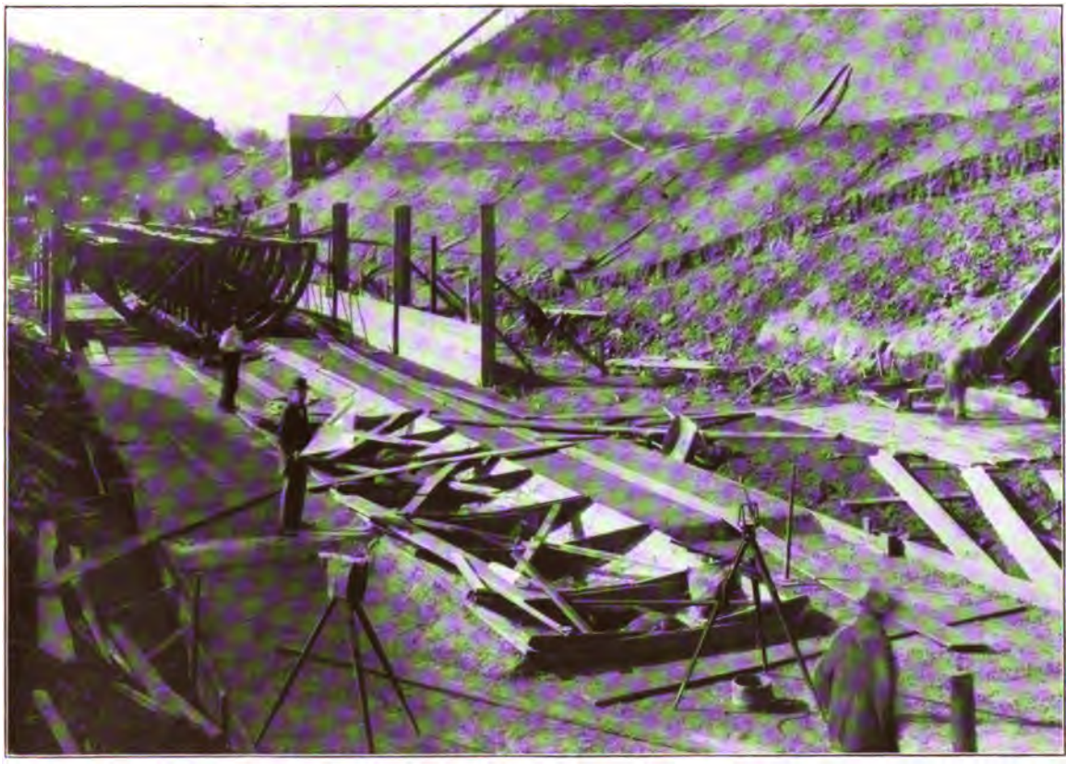

PLATE 34 — Construction of Archway Under Dam, Reservoir No. 1.

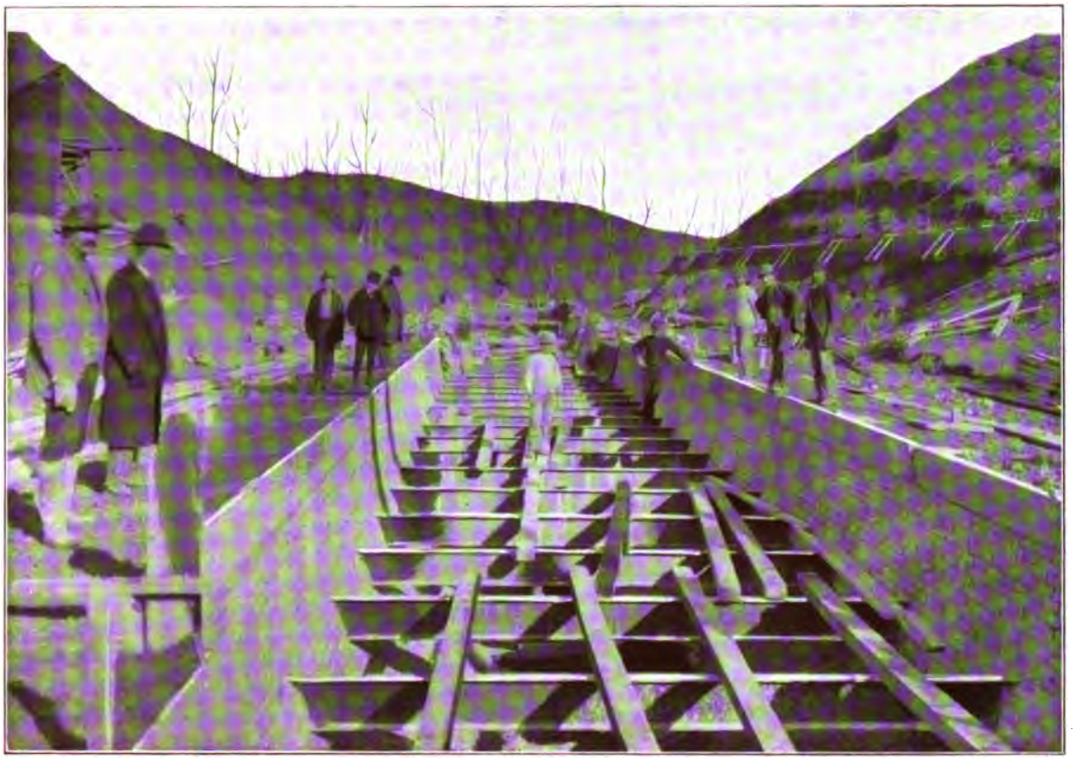

PLATE 35 — Invert of Archway Under Dam, Reservoir No. 1.

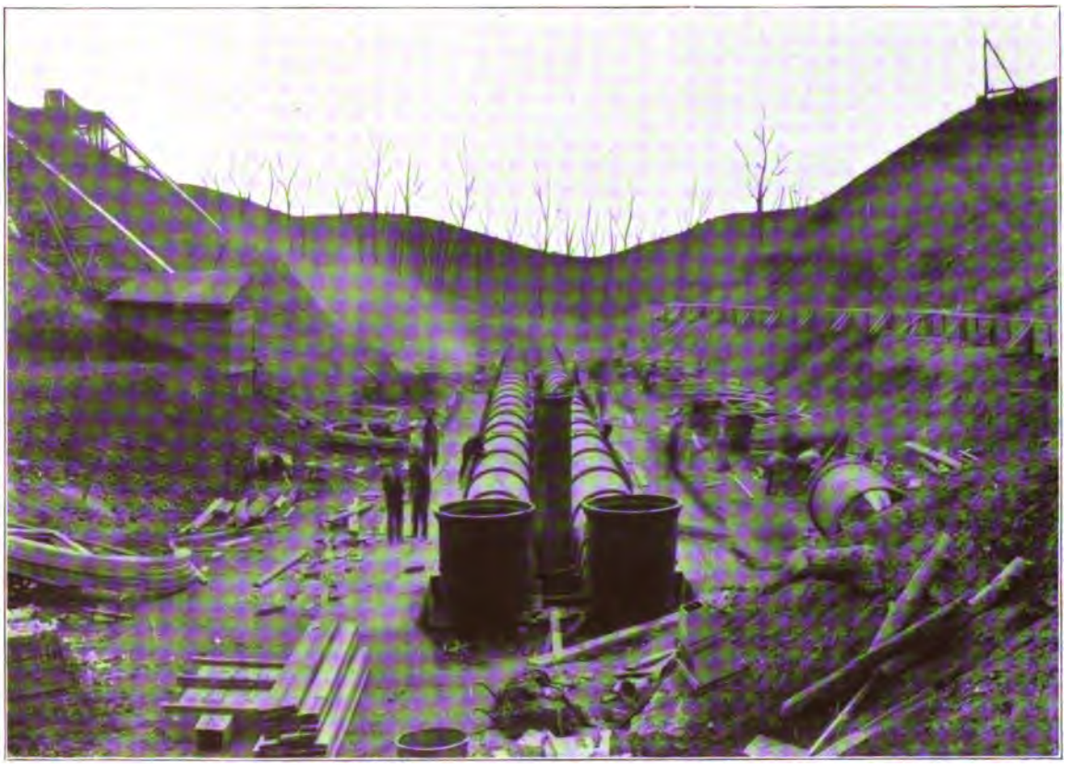

PLATE 36 — Double Line of Sixty-inch Effluent Mains in Archway Under Dam, Reservoir No. 1.

PLATE 37 — Completing Archway Under Dam, Reservoir No. 1.

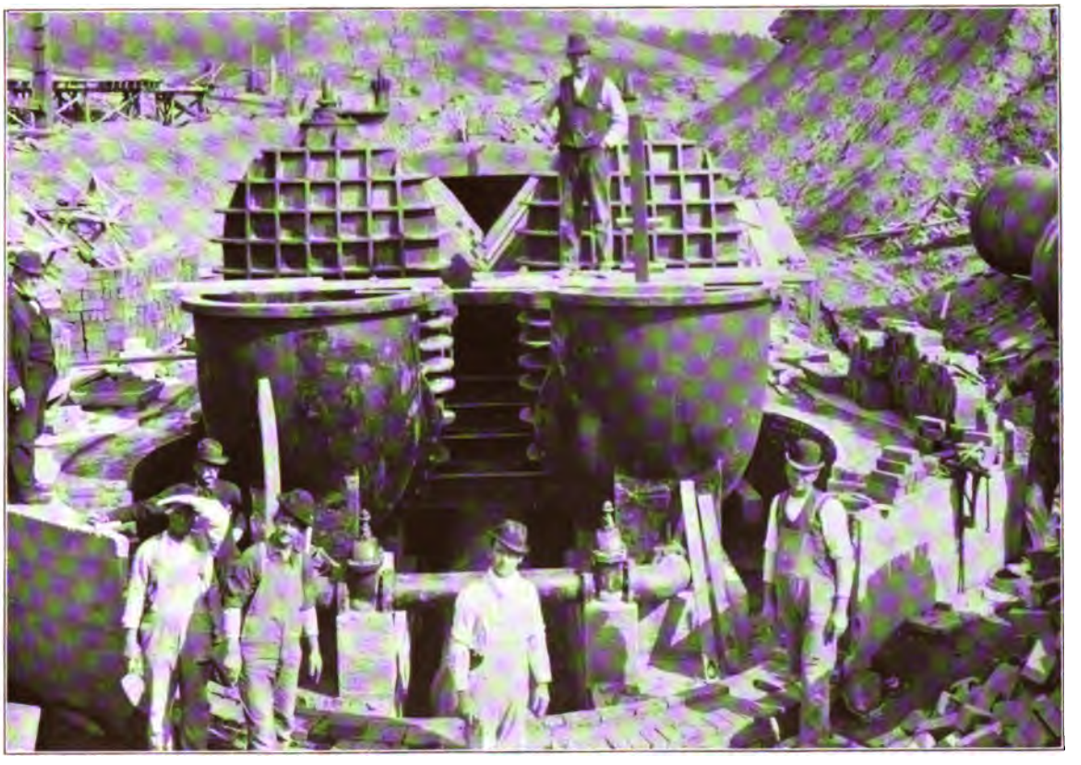

PLATE 38 — Outlet Shaft of Archway Under Dam, Reservoir No. 1.

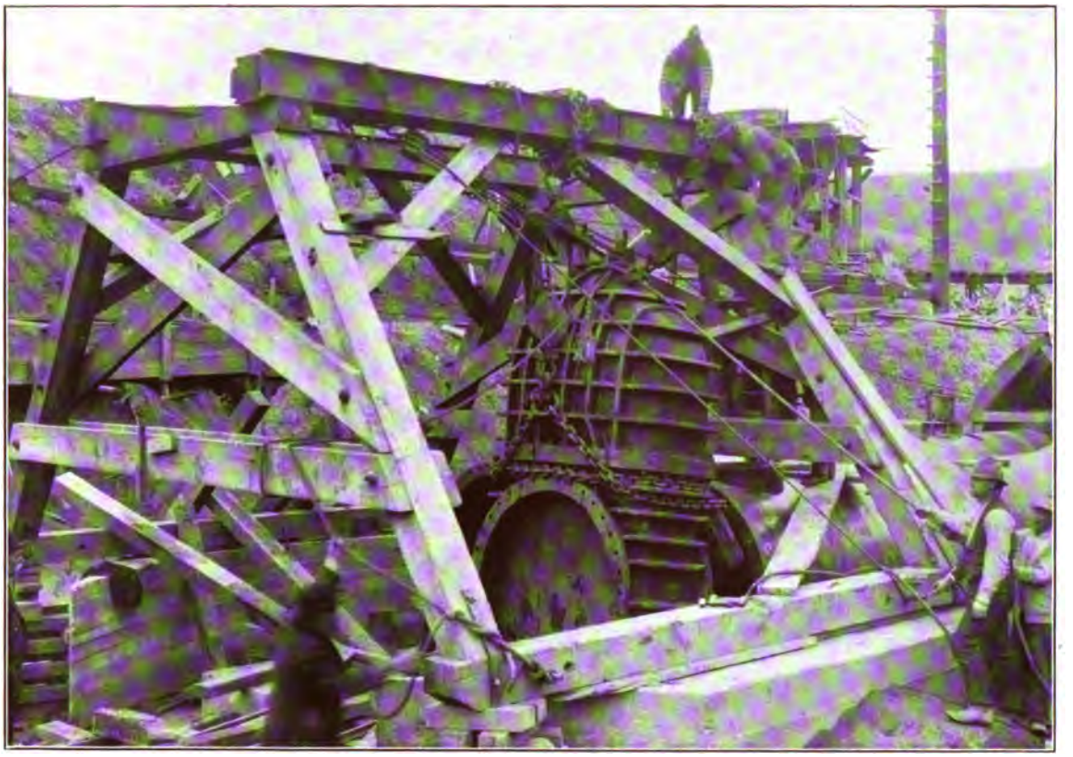

PLATE 39 — Setting Sixty-inch Valve in Shaft of Archway Under Dam, Reservoir No. 1.

PLATE 40 — Reservoir No. 2, Under Construction, August 1, 1902.

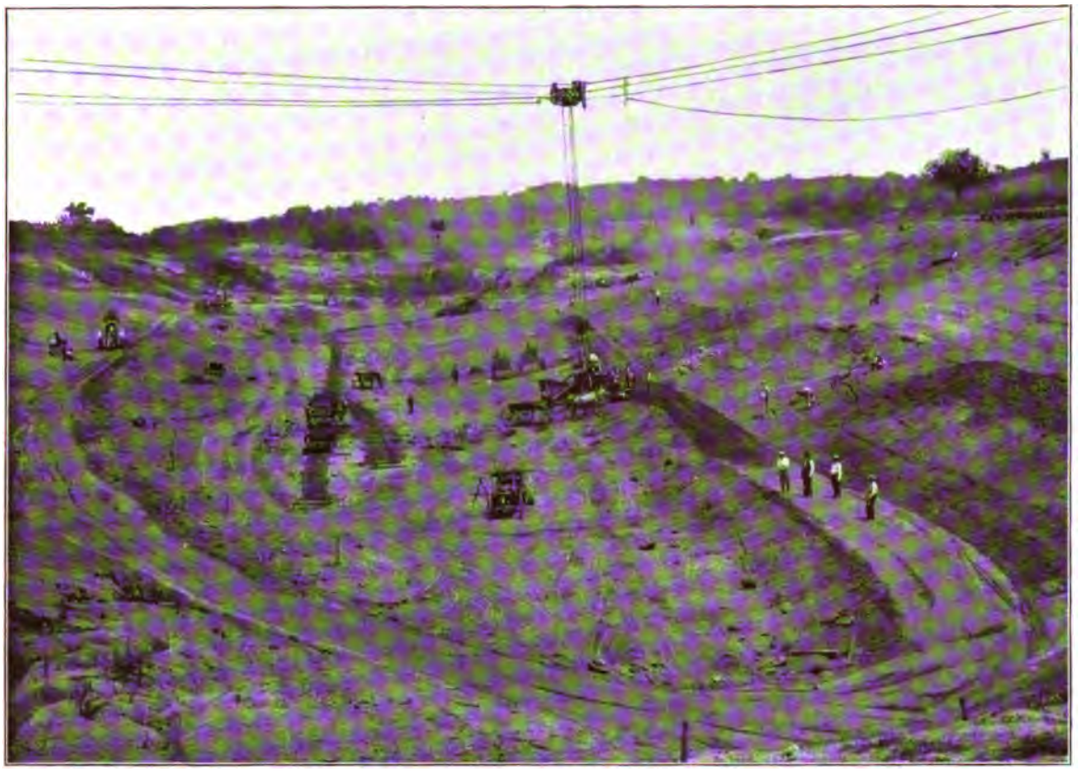

PLATE 41 — Reservoir No. 1, Under Construction, August 3, 1903.

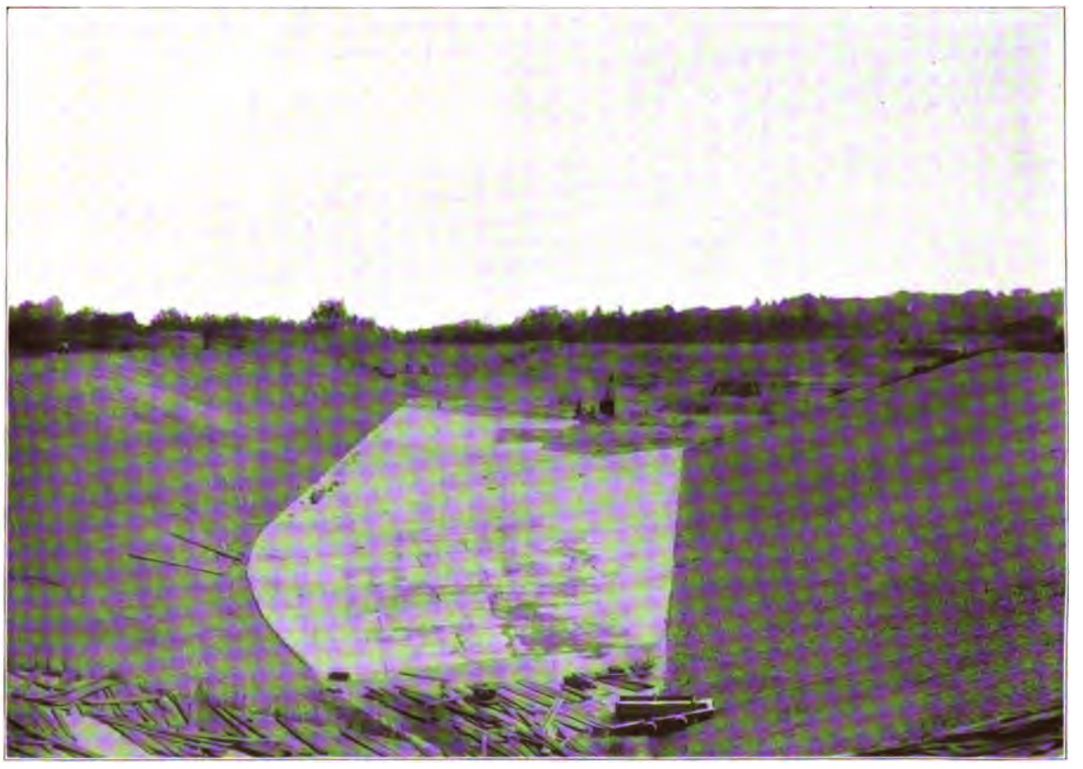

PLATE 42 — Placing Broken Stone and Concrete Revetment, Reservoir No. 1.

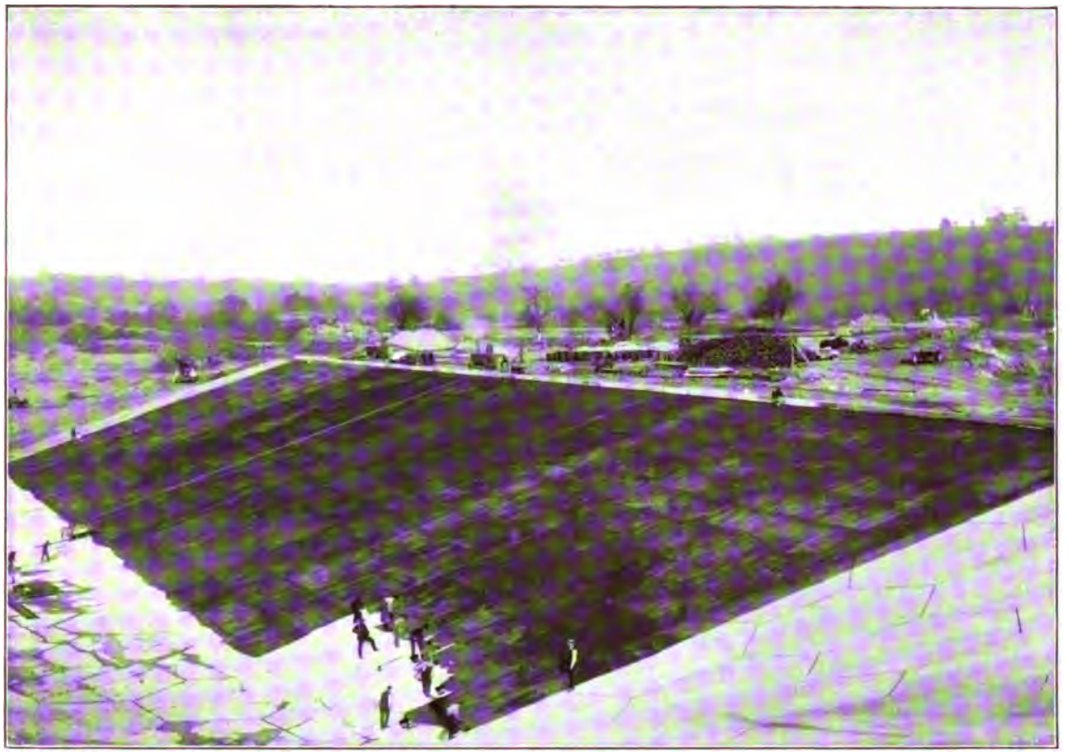

PLATE 43 — Applying Priming Coat to Concrete Revetment, Reservoir No. 1, October 30, 1905.

PLATE 44 — Inlet Cascade of Reservoir No. 1.

PLATE 45 — Floating Tube, Reservoir No. 1.

PLATE 46 — Reservoir No. 2, Under Construction.

PLATE 47 — Reservoirs Nos. 1 and 2 in Service.

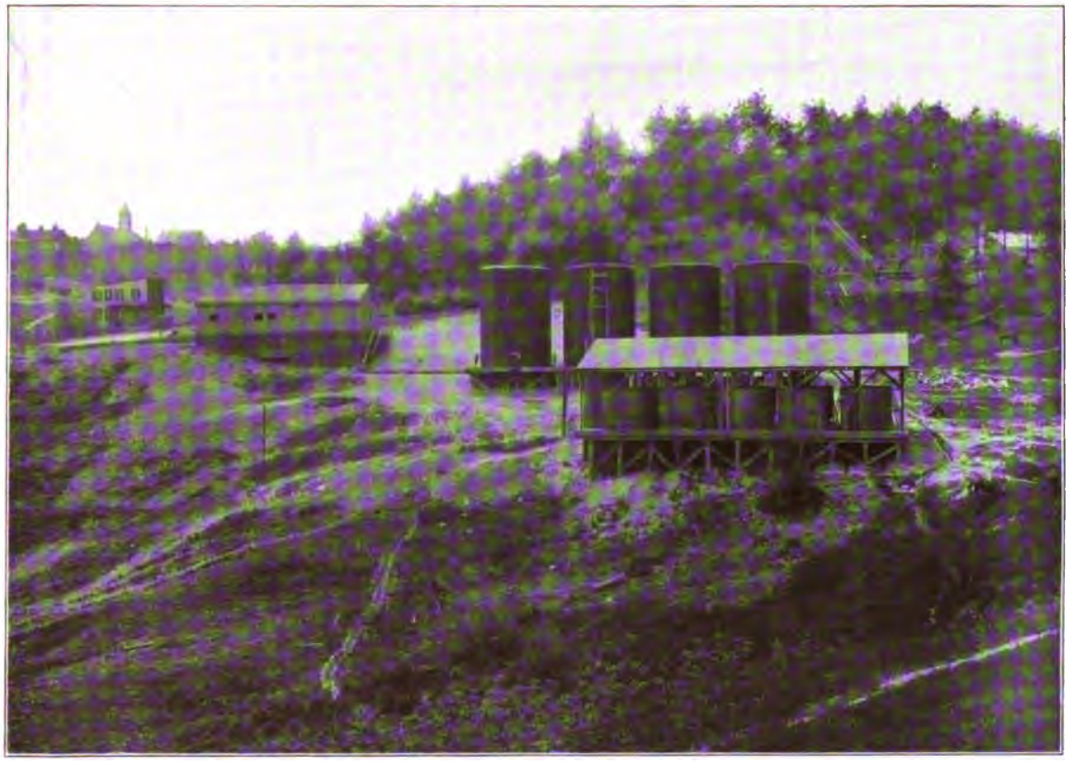

PLATE 48 — Experimental Filter Plant.

PLATE 49 — Excavating Site for Filter Plant.

PLATE 50 — Constructing Concrete Division Wall Between Coagulating Basins 1 and 2.

PLATE 51 — Inlet Pipe, Coagulating Basin No. 3.

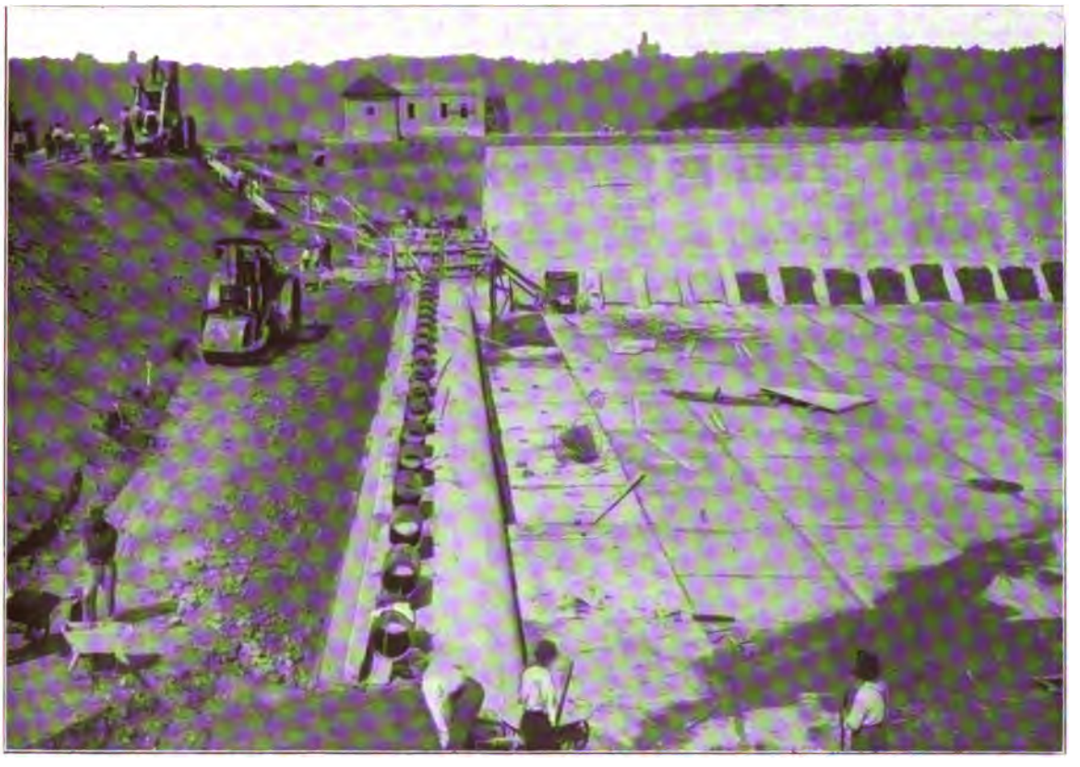

PLATE 52 — Inlet Pipe, Coagulating Basin No. 1.

PLATE 53 — Coagulating Basin No. 2, Completed.

PLATE 54 — Concrete Invert of Pipe Chambers Under Filter Beds, May 30, 1906.

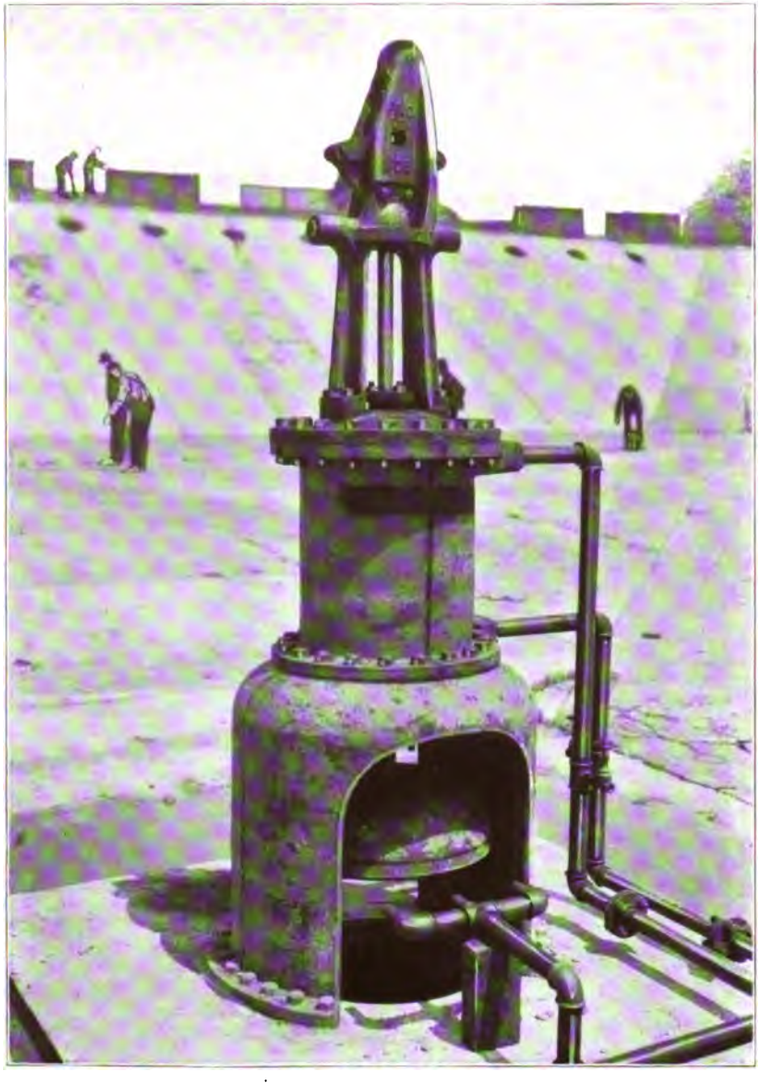

PLATE 55 — Mud Valve.

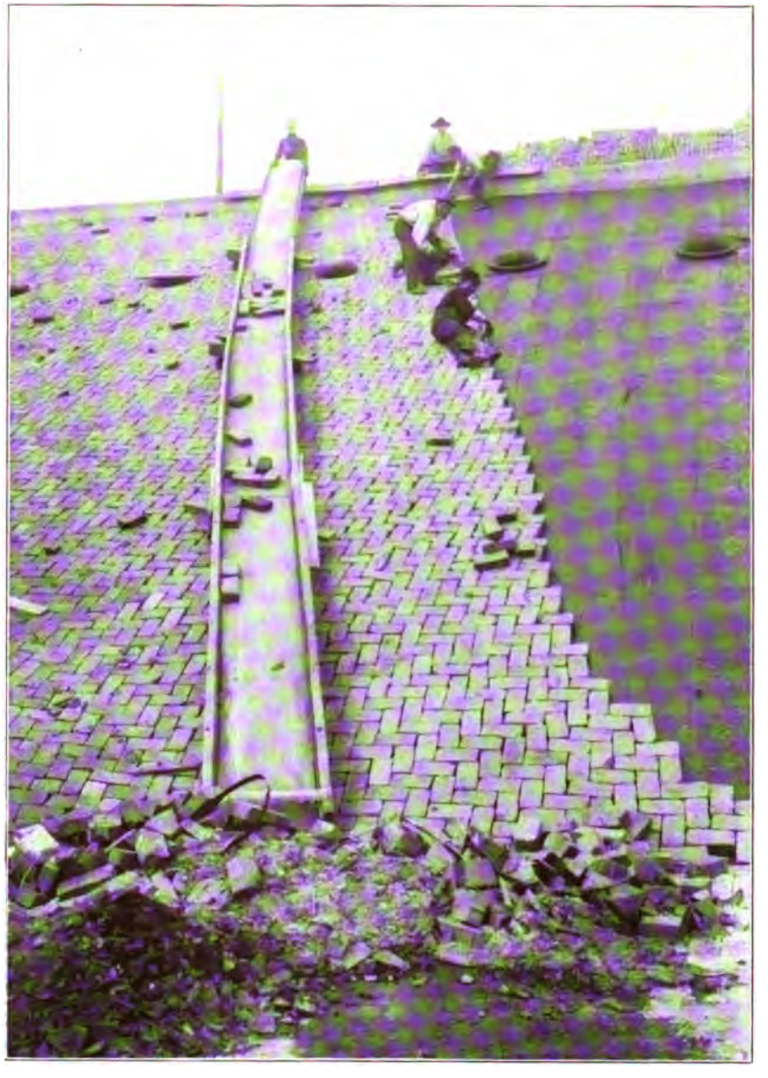

PLATE 56 — Laying Brick Revetment.

PLATE 57 — Effluent Piping Under Filter Beds, July 31, 1906.

PLATE 58 — Piping in Pipe Gallery and Collection Pipes Under Filter Beds, April 2, 1907.

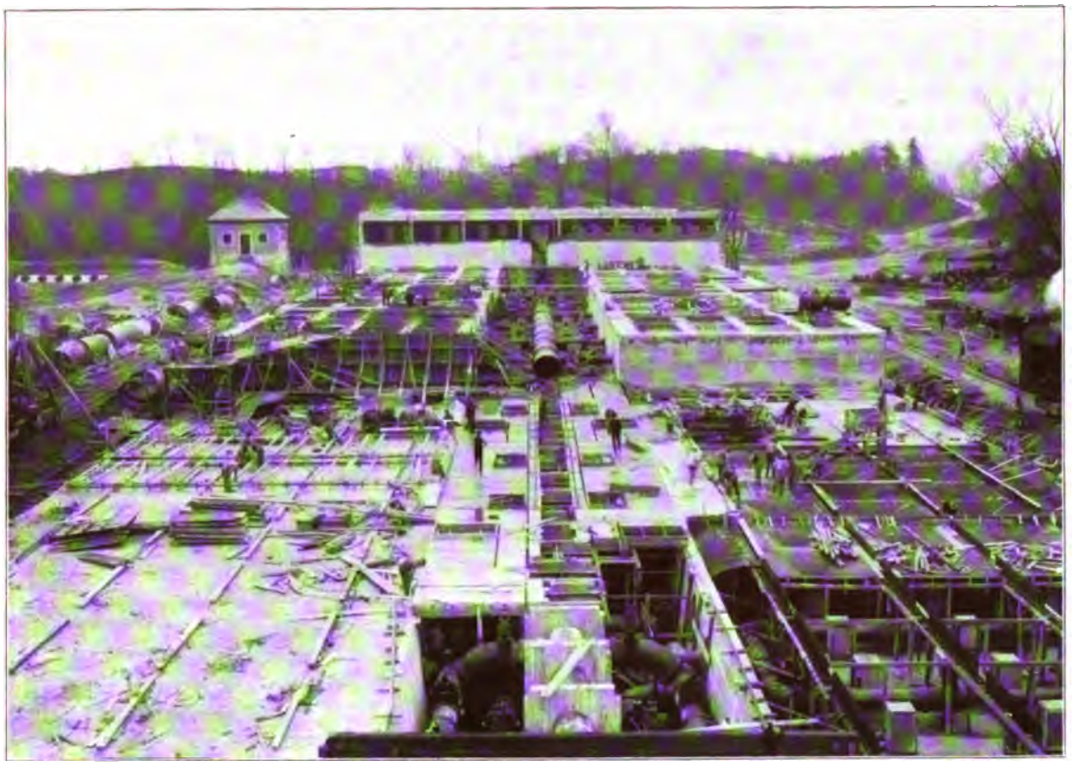

PLATE 59 — Progress of Filter Plant, with Head House in the Distance, May 2, 1907.

PLATE 60 — Concrete Ridges Above Filter Floor.

PLATE 61 — Laying Brass Wire Cloth on Gravel Between Ridges of Filters. May 29, 1907.

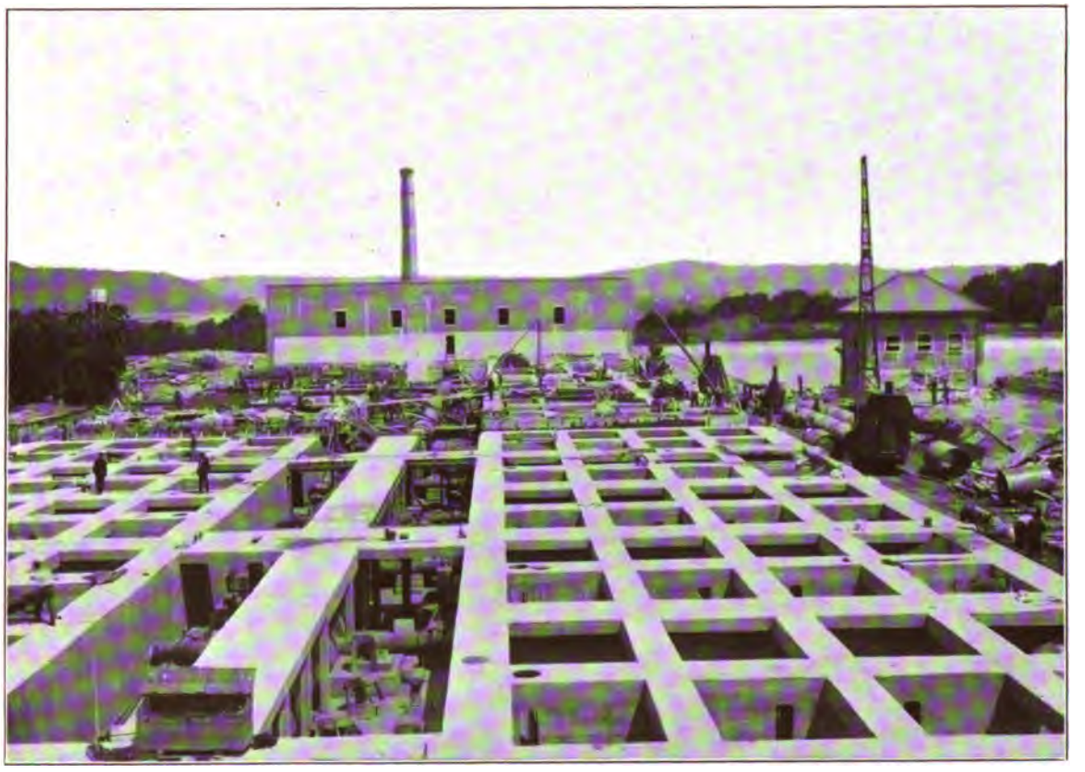

PLATE 62 — Filter House Floor, with Chemical House in the Distance.

PLATE 63 — Interior of Filter House.

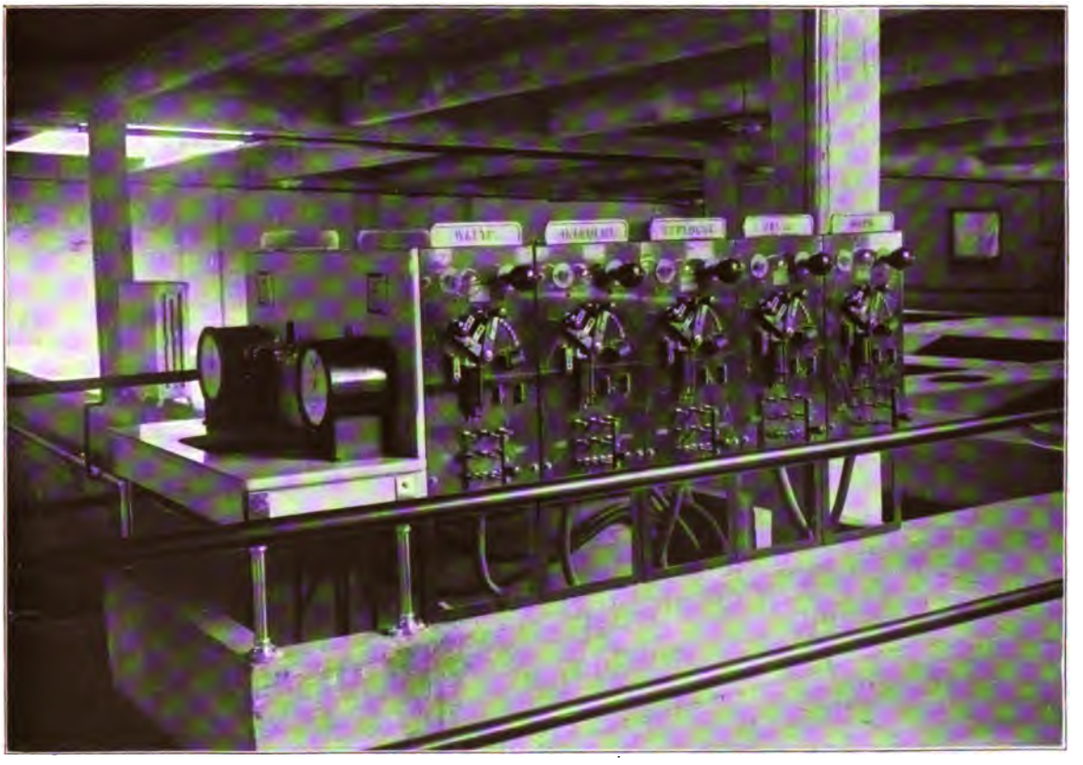

PLATE 64 — Switchboard and Sample Table.

PLATE 65 — Coagulating Basins, with Filter House on the Left.

PLATE 66 — View of Filter Plant from the Southwest.

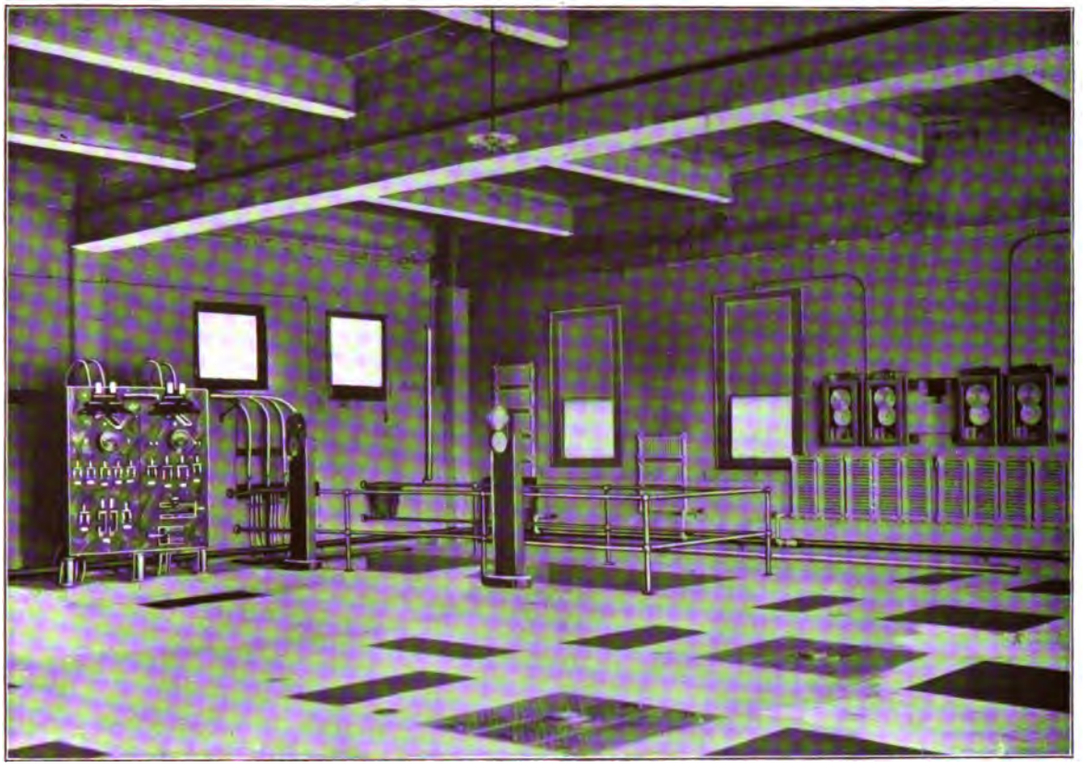

PLATE 67 — Main Switchboard and Gauges in Valve Room of Head House.

PLATE 68 — Lime Saturator Tanks in Chemical House, Under Construction.

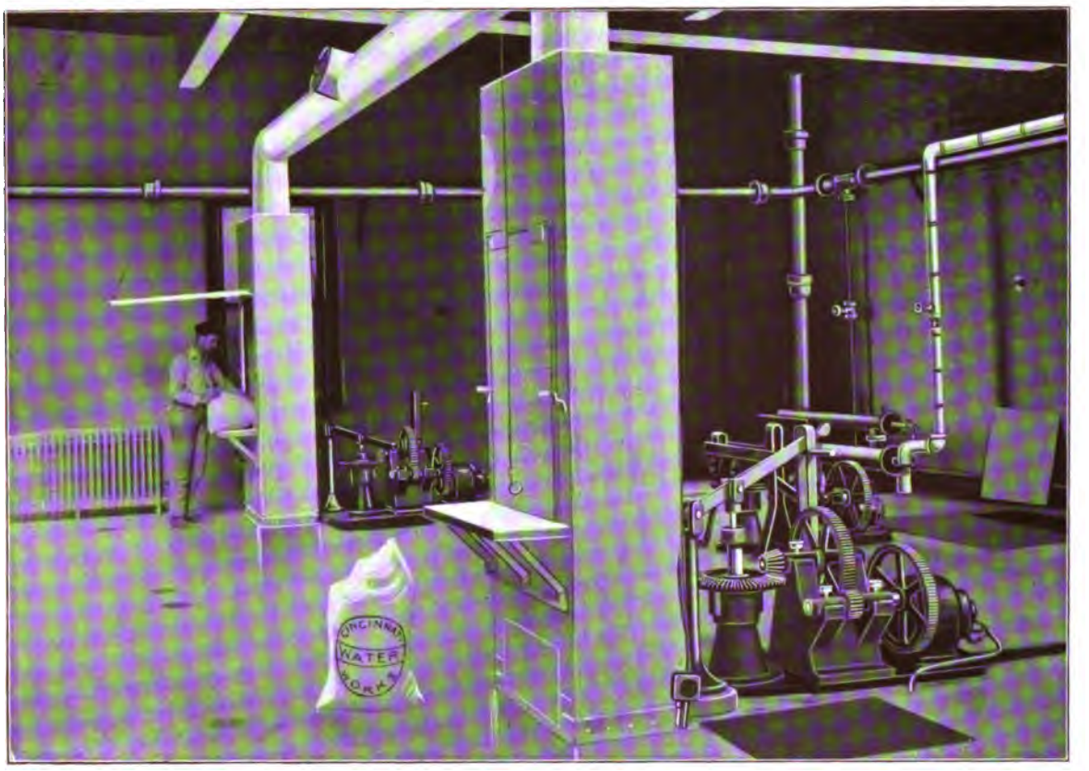

PLATE 69 — Section of Chemical House Used for Making Solution of Lime.

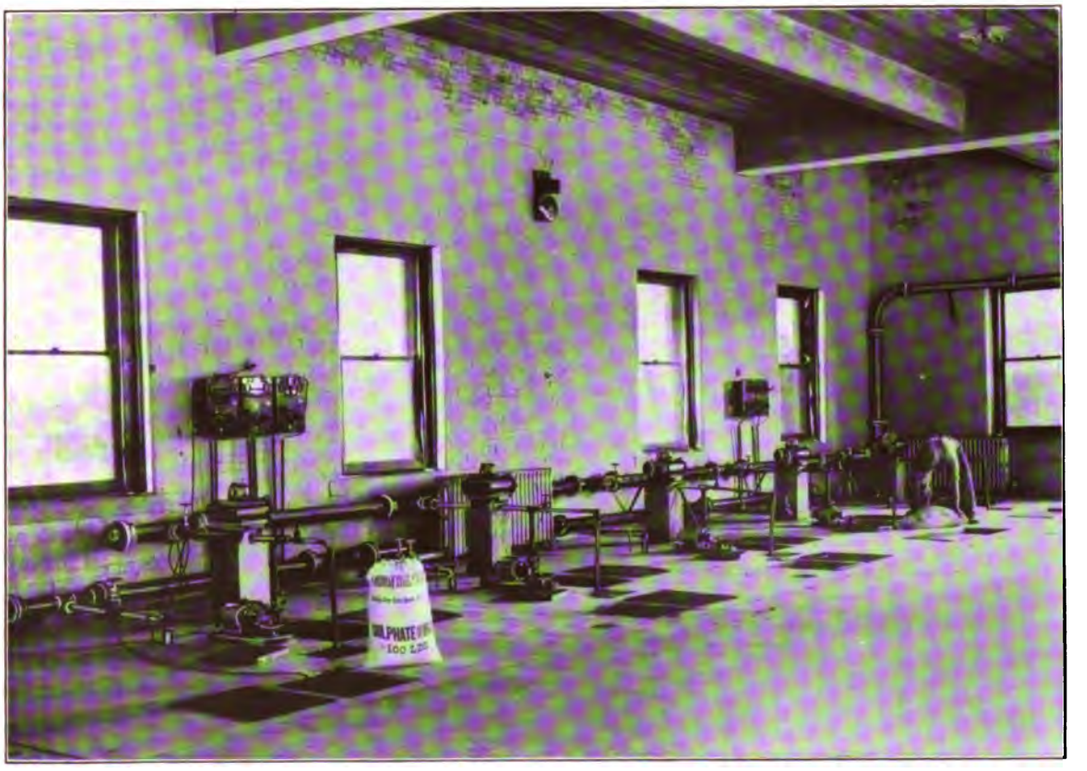

PLATE 70 — Section of Chemical House, Used for Making Solution of Sulphate of Iron.

PLATE 71 — Clear Water Basin in Service, Partly Completed, November 1, 1906.

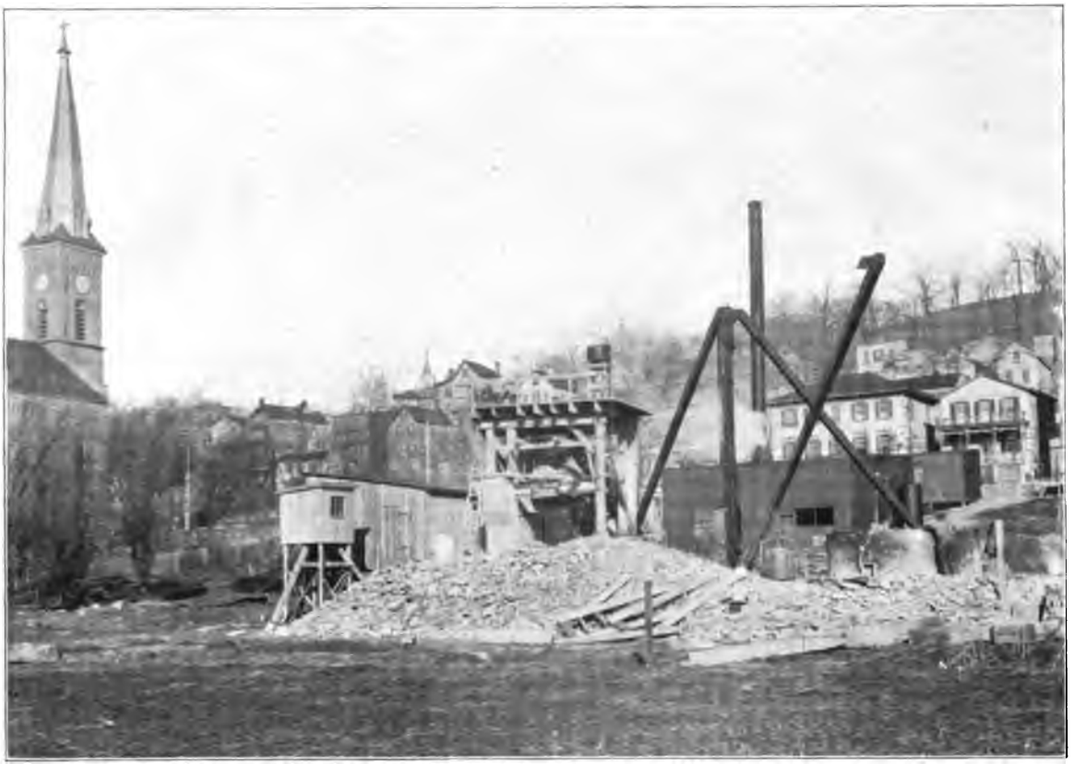

PLATE 72 — Sinking Outlet Shaft of Gravity Tunnel, in rear of Main Pumping Station, April 19, 1901.

PLATE 73 — Interruption of Work on Gravity Tunnel, Due to High Water, April 24, 1901.

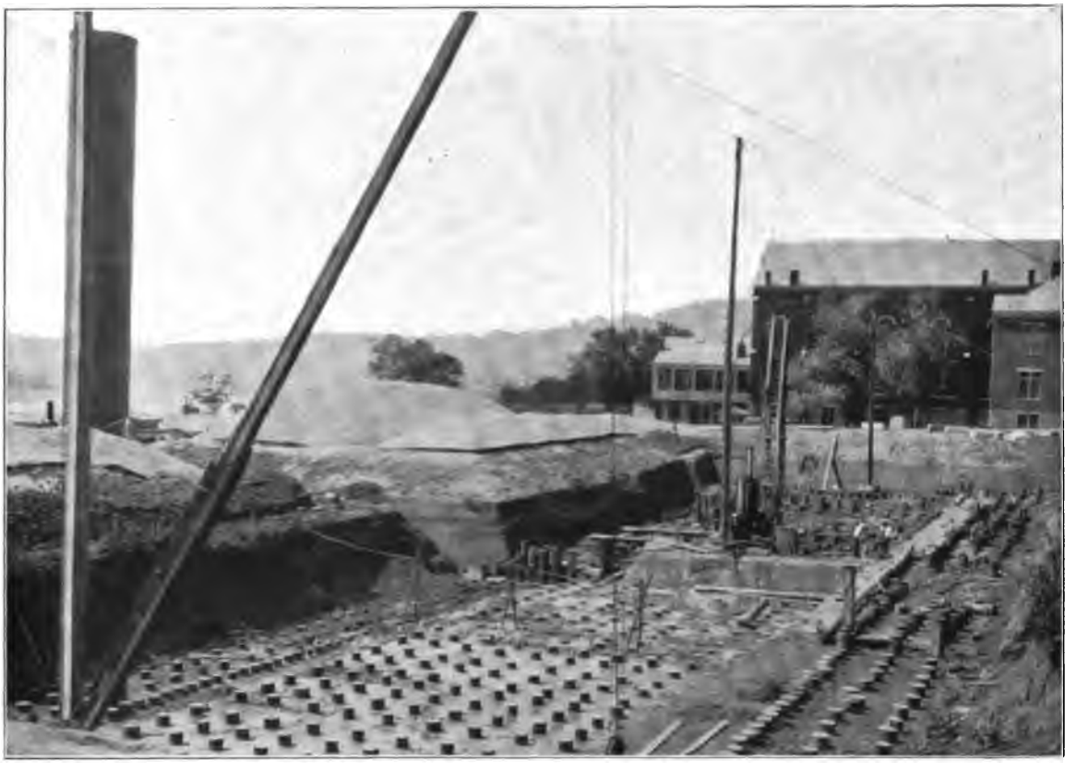

PLATE 74 — Pile Foundations for Pump Pit Walls and Engines at Main Pumping Station.

PLATE 75 — Stand Pipe over Outlet Shaft in Rear of Main Pumping Station.

PLATE 76 — Laying Eighty-four-inch Supply Pipe in Archway at Main Pumping Station.

PLATE 77 — 84-inch by 72-inch by 60-inch Special Casting at Main Pumping Station.

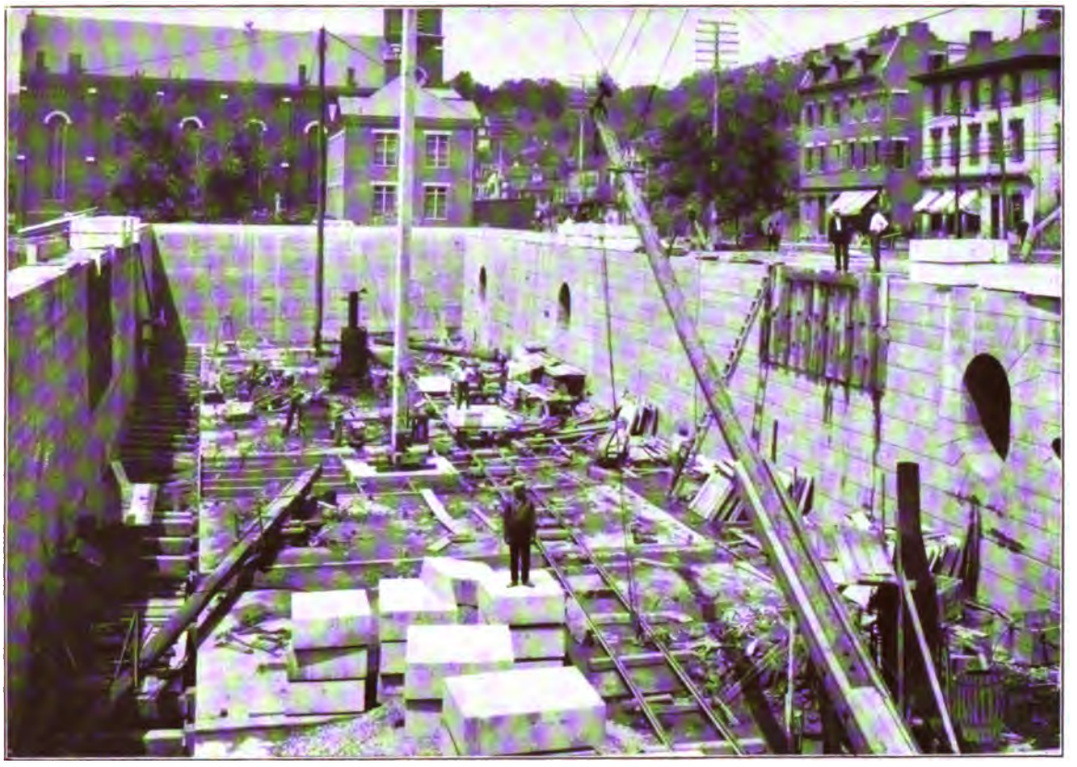

PLATE 78 — Pump Pit at Main Pumping Station, Under Construction.

PLATE 79 — Main Pumping Station.

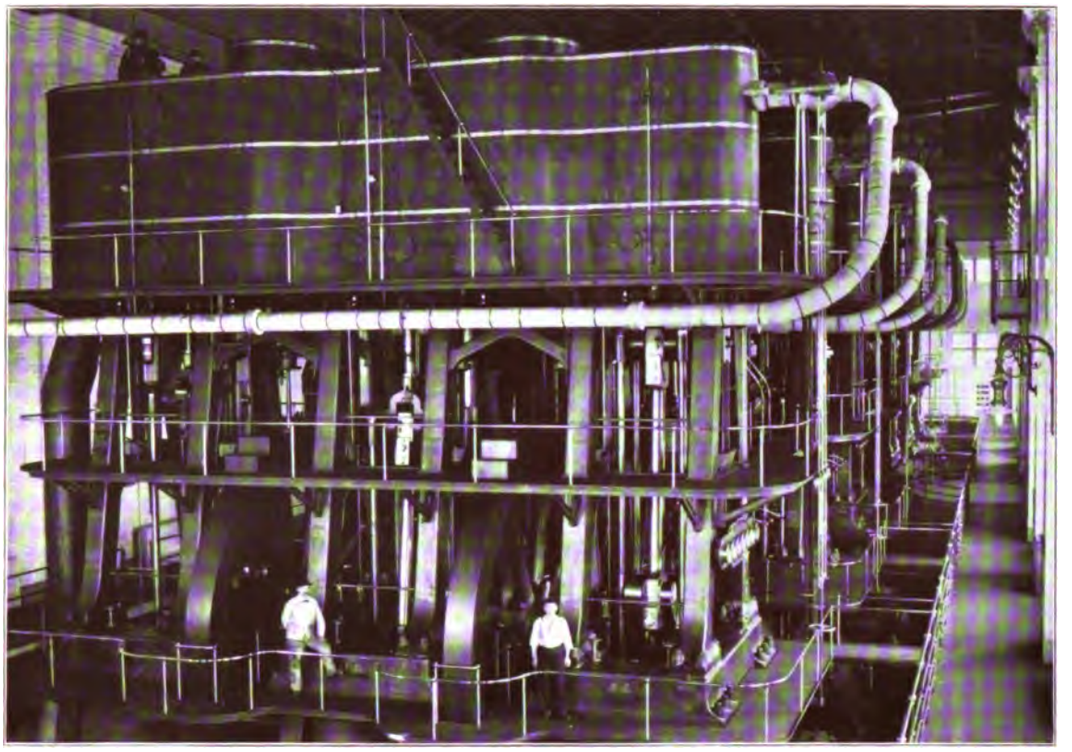

PLATE 80 — Interior of Engine Room at Main Pumping Station.

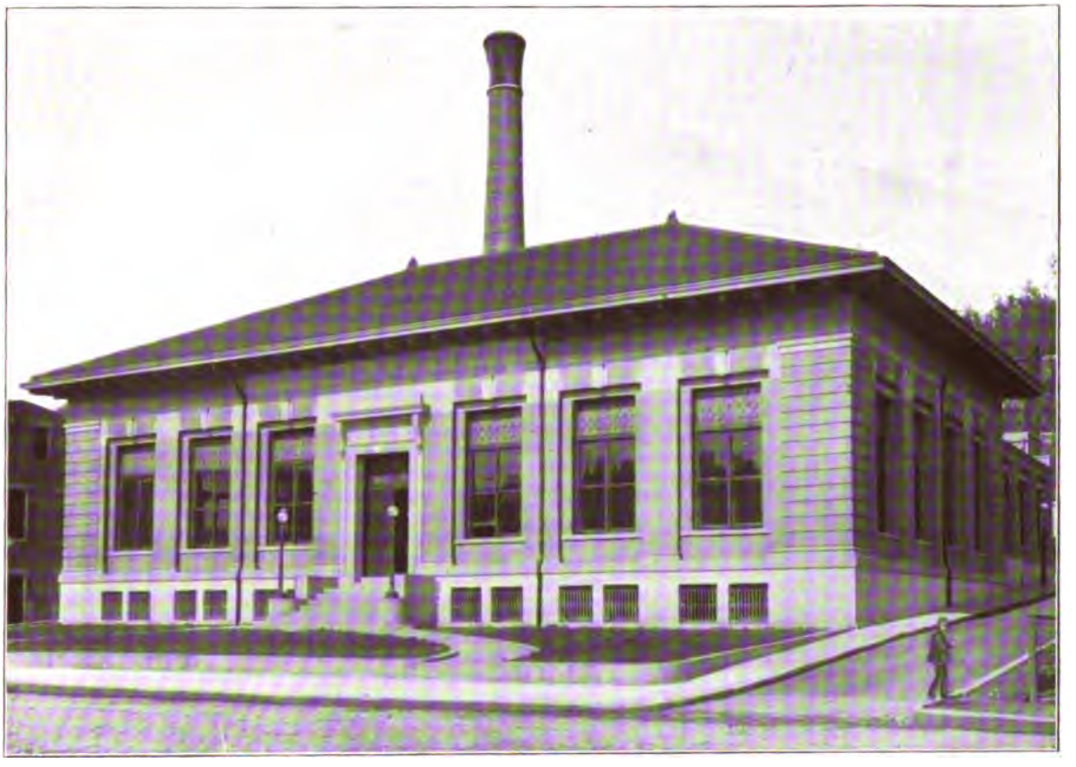

PLATE 81 — Western Hills Pumping Station.

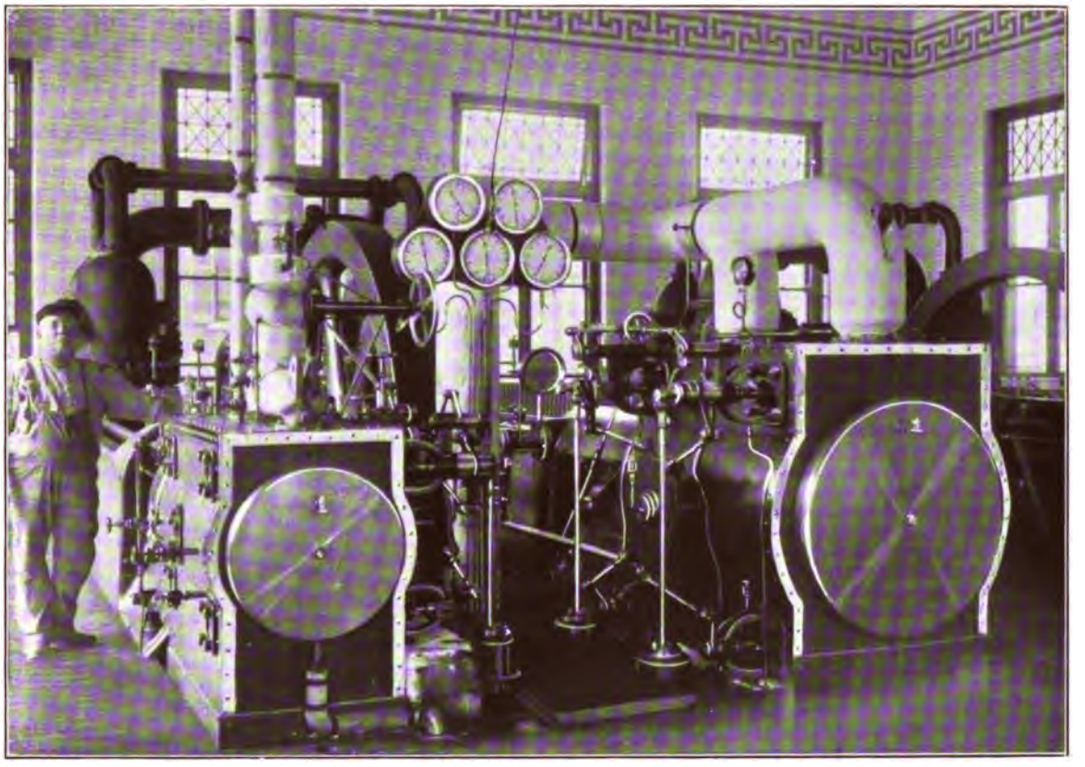

PLATE 82 — Pumps at Western Hills Pumping Station.

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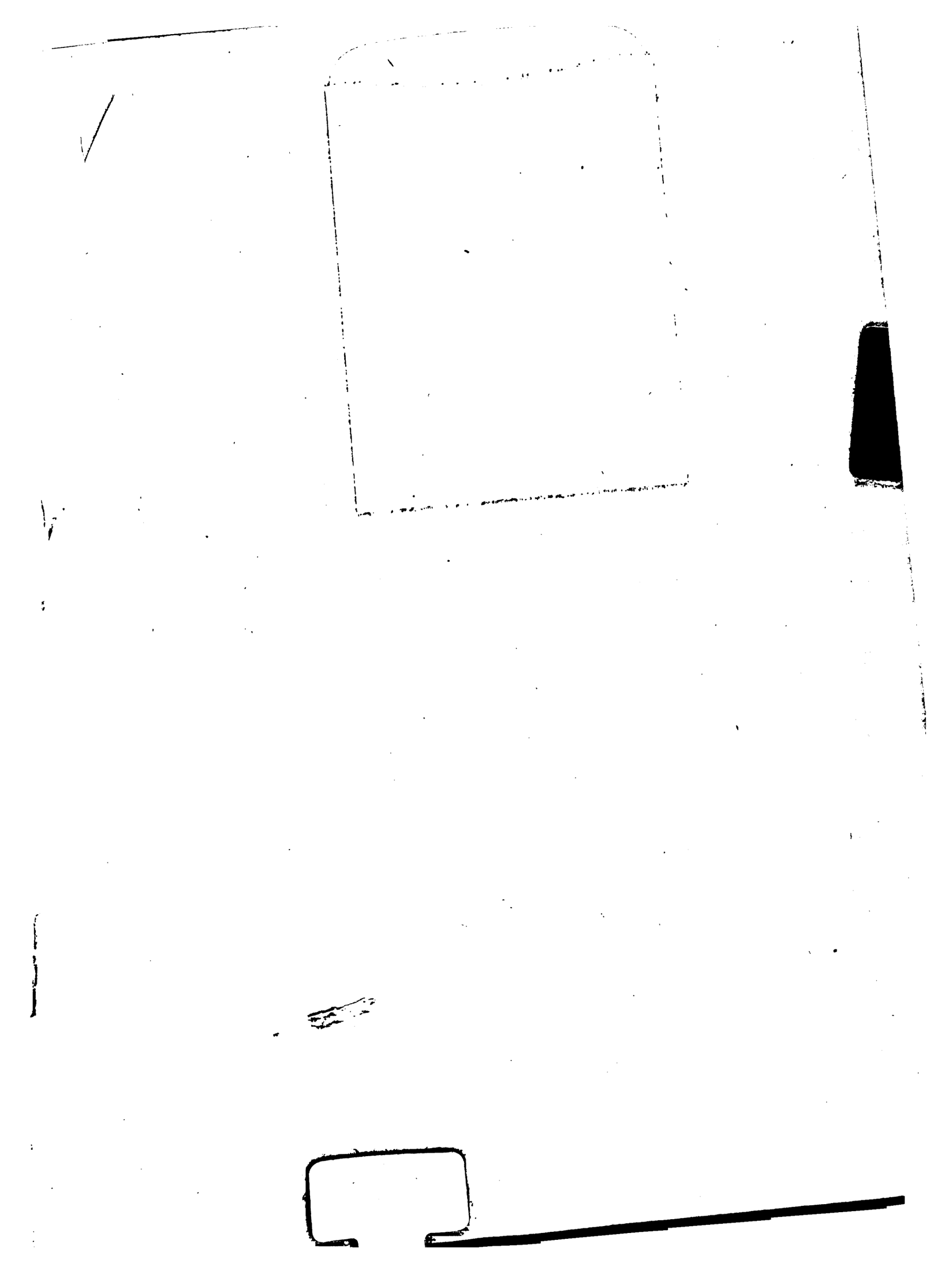

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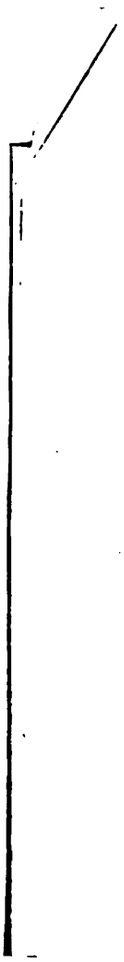
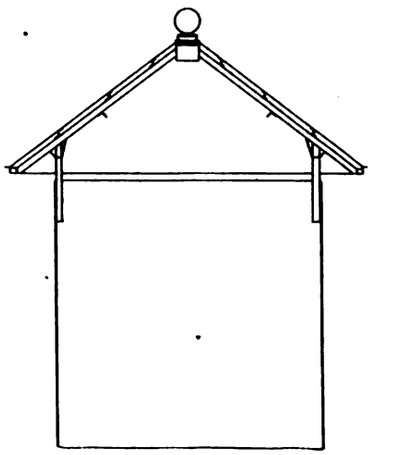
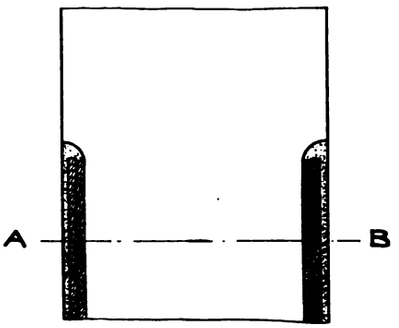
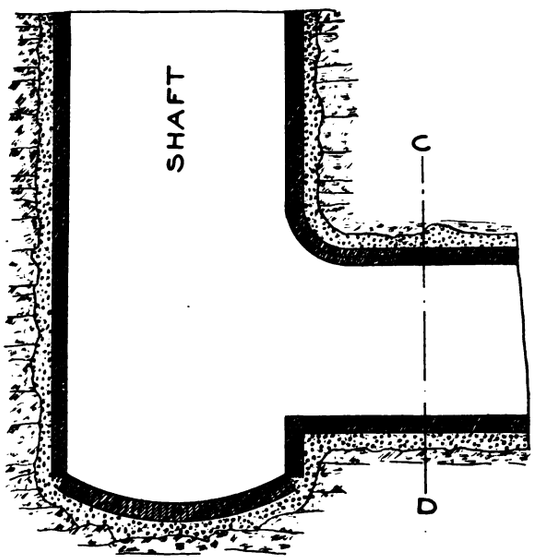
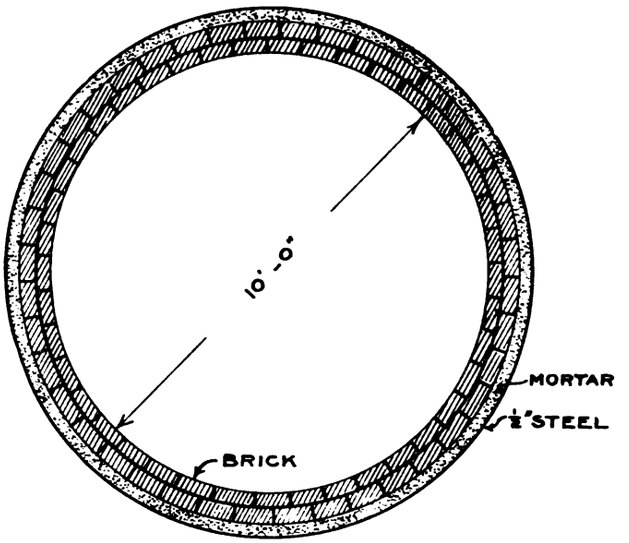


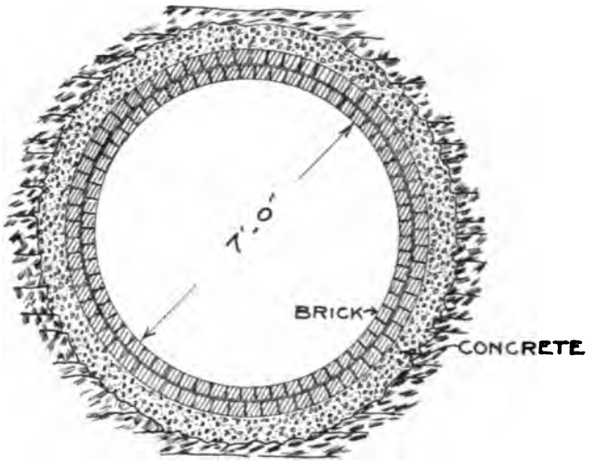






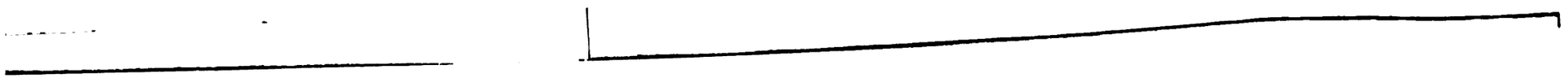


ENLARGED SECTION A-B.



ENLARGED SECTION C-D.

NEW WATERWORKS
FOR THE
CITY OF CINCINNATI
CONSTRUCTED UNDER THE AUTHORITY OF THE
BOARD OF TRUSTEES
"COMMISSIONERS OF WATERWORKS"
SECTIONS OF GRAVITY TUNNEL
AND
WEST END SHAFT.



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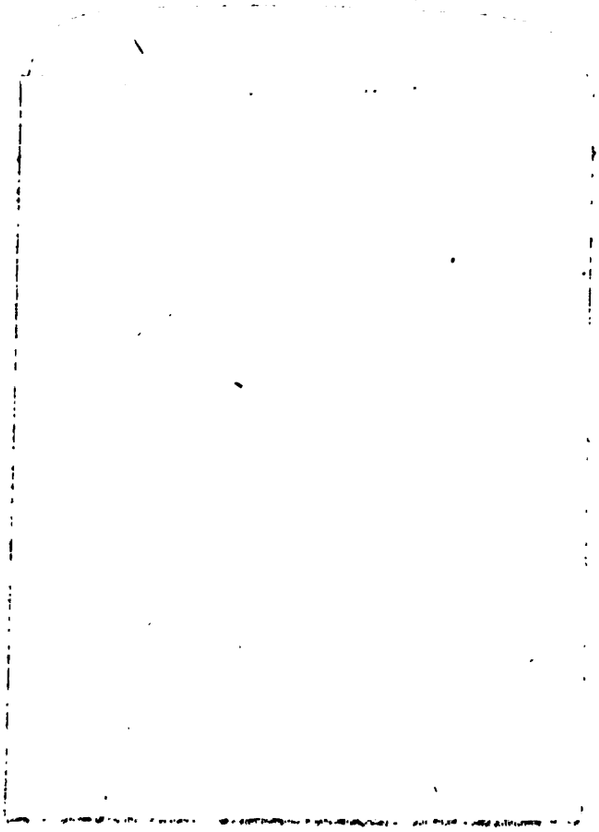
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